Draft

Yakima Subbasin Summary

Prepared for the Northwest Power Planning Council

Editor
Laura Berg
Yakama Nation, Consultant

Subbasin Team Leader
Dave Fast
Yakama Nation

Contributors (in alphabetical order):

Eric Anderson, Washington Department of Fish and Wildlife
Paul Ashley, Washington Department of Fish and Wildlife
F. Dale Bambrick, National Marine Fisheries Service
Ken Bevis, Washington Department of Fish and Wildlife
Jeffrey H. Braatne, University of Washington
Dave Brown, City of Yakima
Duane Calvin, City of Yakima
Brian Cates, U.S. Fish and Wildlife Service
James Cummins, Washington Department of Fish and Wildlife
Doug Eitemiller, Central Washington University
Jeff Feen, Washington Department of Fish and Wildlife
Nick Gayeski, Washington Trout
Melissa Gildersleeve, Washington Department of Ecology
Tracy Hames, Yakama Nation
Donald Haring, Washington Conservation Commission
Joel Hubble, Yakama Nation
Paul James, Central Washington University
John Knutson, Yakima County
Anna Lael, Kittitas County Conservation District
Don Larsen, Washington Department of Fish and Wildlife
Don Larsen, National Marine Fisheries Service
Greenway
Julie Larson, U.S. Bureau of Reclamation/Education
Karen S. Lindhorst, U. S. Forest Service, Naches Ranger District
Tina Mayo, U.S. Forest Service, Cle Elum Ranger District
Scott McCorquodale, Yakama Nation
Charlie McKinney, Wash Department of Natural Resources
Geoff McMichael, Battelle/Pacific Northwest National Laboratory
Scott Nicolai, Yakama Nation
Kate Puckett, U.S. Bureau of Reclamation
Todd Pearsons, Washington Department of Fish and Wildlife
Carol A. Ready, Kittitas County Water Purveyors
Mike Schroeder, Washington Department of Fish and Wildlife
Lee Stream, Washington Department of Fish and Wildlife
Morris Uebelacker, Central Washington University
Matt Vander Haegen, Washington Department of Fish and Wildlife
Paul Wagner, Consultant (Golder Associates for City of Yakima)
Bruce Watson, Yakama Nation
Ginger Wireman, Tapteal

Disclaimer

The Northwest Power Planning Council intended the production of this subbasin summary to be a collaborative effort. Therefore, any party with information relevant to existing natural resources and conditions within the Yakima River subbasin was provided an opportunity to participate in the production of this document. Consequently, the document was created using information collected from many sources. The parties participating in the development and submission of this summary do not imply that they agree with or otherwise support all or any of the information submitted by any other party. All parties reserve the right to respond to and rebut any information within this summary or any document appended to the same, as they may deem appropriate.

Yakima Subbasin Summary

Table of Contents

List of Tables

List of Figures

List of Appendices

Yakima Subbasin Summary

Subbasin Description

Subbasin Location

The Yakima River Subbasin is located in south central Washington (Figure 1). The city of Yakima is the largest city and is centrally located in the subbasin. The basin or subbasin includes most of Yakima and Kittitas counties as well as small portions of Benton and Klickitat counties. The most of the Yakima Nation Reservation is located within the subbasin.

Figure 1. Map showing the location of the Yakima subbasin

Drainage Area

The Yakima River drains an area of 15,900 square km (6,155 square miles) and contains about 3058 km (or about 1,900 river miles) of perennial streams. Originating near the crest of the Cascade Range above Keechelus Lake (Figure 1), the Yakima River flows 344 km (214 miles) southeastward to its confluence with the Columbia (RM 335.2).

Major tributaries include the Kachess, Cle Elum and Teanaway rivers in the northern part of the subbasin, and the Naches River in the west. The Naches has four major tributaries, the Bumping, American, Tieton and Little Naches rivers. Ahtanum, Toppenish and Satus creeks join the Yakima in the lower subbasin. Figure 1 shows the basin's major rivers. Six major reservoirs are located in the subbasin and form the storage component of the federal Yakima Project, managed by the Bureau of Reclamation. The Yakima River flows out of Keechelus Lake (157,800 acre feet), the Kachess River from Kachess Lake (239,000 acre feet), the Cle Elum River from Cle Elum Lake (436,900 acre feet), the Tieton from Rimrock Lake (198,000 acre feet), and the Bumping from Bumping Lake (33,700 acre feet). The North Fork of the Tieton River connects Clear Lake (5,300 acre feet) with Rimrock Lake. All reservoirs except Rimrock and Clear Lake were natural lakes before impoundment. The non-federal Wenas Dam stores irrigation water for use in the lower Wenas Valley in the middle subbasin.

Climate

The climate of the Yakima Subbasin ranges from cool and moist in the mountains to warm and dry in the valleys. Annual precipitation near the Cascade crest ranges from 80 inches to 140 inches, whereas the lower elevations in the eastern part of the subbasin receive 10 inches or less. Summer temperatures average 55º F in the mountains, and 82º F in the valleys. In the summer, air from the interior of the continent usually results in high temperatures. Winter temperatures are fairly moderate. The Selkirk Mountains in Idaho and the Rocky Mountains in British Columbia shield the area from the very cold air masses that sweep down from Canada into the Great Plains. The predominantly westerly winds in the winter allow the area to benefit from the coastal maritime influence. Average maximum winter temperatures range from 25º to 40º F, while average minimum winter temperatures range from 15º to 25ºF. Minimum temperatures of minus 20º o minus 25º F have been recorded in most areas.

A sharp precipitation gradient in the subbasin falls off in a generally southeasterly direction. Orographic cooling of moist maritime air passing over the Cascades results in heavy precipitation on the windward slope and near the crest, and a rain shadow to the east. In a distance of 10 miles, annual precipitation falls from 100 inches or more at the crest of the Cascades to 48 inches at Bumping Lake and to 26 inches at Rimrock Dam. Within the next 15 to 20 miles, precipitation decreases to 8 to 10 inches on the valley floor. Virtually all of the streams in the subbasin originate at higher elevations where annual precipitation is 30 inches or more (note Status~30", Toppenish~45, etc.).

The rainy season in the valleys occurs during November through January, when about half the annual precipitation occurs. Snowfall in the valleys ranges from 20 to 25 inches and from 75 inches at 2,500 feet to over 500 inches at the summit of the Cascades. It is this mountain snow pack that provides most of the water for irrigated agriculture and streamflow.

Topography

The topography of the Yakima River Subbasin includes a variety of land forms and land cover (Figure 2). In the higher elevations of the Cascade Mountains there are glaciated peaks and deep u-shaped valleys. The upper mainstem Yakima and Naches River and several tributaries occupy broad valleys excavated by alpine glaciers. Lowlands typical of landforms associated with the Columbia Plateau are found along the lower half of the Yakima River (TriCounty Water Resource Agency et al., 2000). Elevations in the subbasin range from over 2,438 m (8,000 feet) in the Cascades, above Keechelus Lake where the river originates, to about 104 m (340 feet) at the confluence of the Yakima and Columbia rivers. (Rinella, et al. 1992)

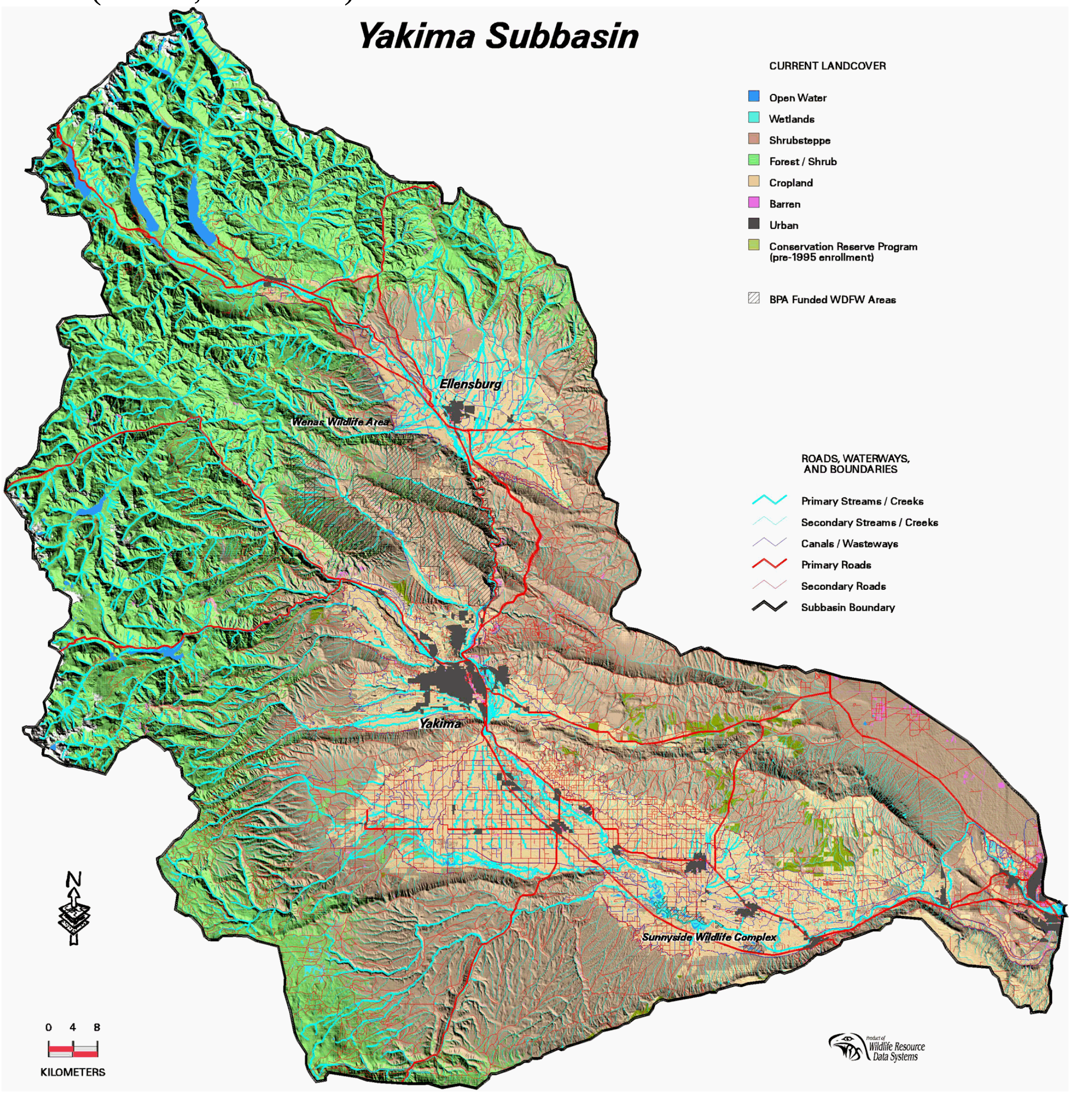


Figure 2. Current landcover in the Yakima subbasin

Topography in the subbasin is characterized by a series of long ridges extending eastward from the Cascades and encircling flat valley areas. The ridges rise 1,000 to 3,000 feet above the adjacent valley floors (Tri-County Water Resource Agency et al. 2000).

Geology

The Yakima River Subbasin straddles two very different physiographic and geologic provinces, the Cascade Mountains in northwestern part of the basin and the Columbia Plateau to the southeast. The Cascade Mountains consists of continental formations of Eocene-age sandstone, shale and some coal layers, and pre-Miocene volcanic, intrusive and metamorphic formations. Tertiary and quaternary age andesite and dacitic lavas, tuff and mudflows from a broad north-south arch along the western edge of the Yakima Basin (Tri-County Water Resource Agency et al. 2000).

The principal rock of the Columbia Plateau is a series of basalt flows of tertiary age that cover older rock and lap onto the western edge of the Cascade Mountains. The majority of these basalt flows, interspersed with sedimentary layers is called the Columbia River Basalt Group. This thickness of the Columbia River Basalt Group within the lower and middle Yakima River basin ranges from 9,000 to 12,000 feet, growing thicker the down stream direction (TriCounty Water Resource Agency et al., 2000). The basalt plateau of the eastern basin was subsequently folded and faulted into a series of northwest-southeast trending anticlinal ridges and synclinal valleys, called the Yakima Fold Belt, valleys that extend from the Cascades to the broad plains of the Columbia River. The antecedent Yakima River incised canyons and water gaps through the ridges and deposited gravels, eroded from uplifting mountains and ridges, in the valleys.

Alpine glaciers draining the Cascade crest down the Yakima and Naches valleys delivered large volumes of glacial outwash to the alluvial basins, resulting in partial filling of Cle Elum, Kittitas and upper and lower Yakima valleys with sand, gravel, and silt. Glaciation left many lakes (four of which were expanded to serve as storage reservoirs). Backwaters from the Ice-age Lake Missoula flood left thick silt deposits in the lower valley.

Extensive portions of the eastern and southeastern subbasin are mantled by loess, a wind-deposited silt derived from outwash deposits.

Soils

Seven soil associations exist in the Yakima Subbasin. Four of these associations, (Weirman-Zillah, Renslow-Ritzville, Naches-Woldale and Warden-Shano), comprising about 18 percent of the subbasin area, are located in gently sloping areas and are subject to intensive irrigated agriculture. These soil types are fine textured and easily eroded.

The soils are part of the Rough Mountainous Land Association and were formed in glacial till or outwash. They are of variable depth, stony, broken by outcrops of underlying rock, and valuable for timber production, summer grazing, wildlife habitat, recreation and, chiefly, as a watershed. In its role as watershed, this area merits protection from fires, erosion and uncontrolled development. The Rough Mountainous Land Association makes up 48 percent of the subbasin. Soils on the ridge tops generally consist of the Rock Creek-Starbuck Association, and are shallow, well drained and stony, and are formed in loess and loess mixed with weathered basalt. Topography is gently sloping to very steep along the drainages and hillsides. This association is valuable chiefly as range or wildlife habitat although carrying capacity is low. Much of the area has been overgrazed. The Rock Creek-Starbuck Association makes up 33 percent of the subbasin.

Intensive, irrigated agriculture occurs only on the remaining 19 percent of the soils of the subbasin, which lie in valley bottoms and along the shoulders of the ridges. Most of the soils in this area are very fine, wind-deposited silts and sands with large erosion potential on slopes in excess of 2 percent (Boucher 1984).

Vegetation

Vegetation in the subbasin is a complex blend of forest, range and cropland (Figure 2). Over one-third of the land in the Yakima Subbasin is forested. Rangeland lies between cultivated areas, located in the fertile lower valleys, and the higher-elevation forests.

Forests predominate at higher elevations. Moisture and topography dictate the character of the forests in the subbasin. Along the eastern fringe of the timber zone, timber stands are scattered and occur mainly as narrow bands of trees in canyon bottoms. These meandering strips of timber merge into sparse ponderosa pine and Oregon white-oak forests, which in turn give way to denser stands of mixed species in the higher moisture and elevation zones. As a result, a large portion of the timber volume is in a 30-mile-wide band following the crest of the Cascades. Forests in the subbasin are heterogeneous in species composition, age and size class, in part, because of the different management objectives of the various landowners and, in part, because of the sharp gradient in moisture transition zones. In past years, large acreages have been clearcut in the Snoqualmie Pass area and in the upper Little Naches drainage. The cumulative effect on the ecological integrity of the streams that drain the upper Yakima River is a matter of great concern.

Between the forests and the valley floor lie the rangelands. Almost all shrub-steppe habitats in the subbasin are supported by highly fragile soils that are easily eroded. The four major plant associations in the Yakima Subbasin are the big sagebrush-bluebunch wheatgrass association (40 percent of existing rangeland), the three-tip sagebrush-Idaho fescue association (5 percent existing rangeland), the bitterbrush-bluebunch-wheatgrass association (35 percent existing rangeland) and the Sandberg bluegrass-stiff sagebrush association (20 percent existing rangeland). Except for the small three-tip sagebrush-Idaho fescue association, over 50 percent of all shrub-steppe associations are in fair to poor condition today. The increased runoff and erosion from these areas may have a significant impact on water quality.

Riparian conditions are extremely varied, ranging from severely degraded to nearly pristine. Good riparian habitat generally is found along forested, headwater reaches, whereas degraded riparian habitat is concentrated in the valleys, frequently associated with agricultural activity, especially grazing streamside tillage or mowing. Recreational development is having an increasing impact, especially along the Yakima River in the critical reach from the city of Cle Elum to Easton Dam.

Hydrology

The Columbia River basalts, located within the Columbia Plateau, represent a locally important aquifer system including interbeds and overlying sediments. The overlying alluvial aquifers are highly permeable and are heterogeneous and anisotropic, due to their deposition within the fluvial environment where the processes of cut and fill alluviation by the Yakima River and tributaries occurred. The rocks of the Cascade Mountain province store and transmit little water via aquifer systems, and the majority of runoff occurs as overland flow.

In both the Cascade and Columbia Plateau regions, recent glacial activity and the network of tributary and main channel flow deposited large amounts of lacustrine and fluvial material in the valleys. This geologic template produced a series of groundwater basins separated by natural knick points (e.g., Selah and Union Gaps) and longer canyons (e.g., Yakima Canyon) (Kinnison and Sceva 1963). The Yakima River cuts through four large subbasins (Rosyln, Kittitas, Upper Yakima and Lower Yakima). This geological setting influences the hydrologic cycle.

Historically, the hydrologic cycle in each basin was characterized by extensive exchange between the surface, hyporheic and groundwater zones (Kinnison and Sceva 1963; Ring and Watson 1999). This exchange would have occurred mainly in the vast alluvial valleys and flood plains, which would have functioned as hydrologic buffers, distributing the energy of peak flows and moving cool, spring melt water out onto the flood plains. This inundation would annually recharge the shallow, surficial aquifers; a process that would occur potentially well into summer due to extensive and long-lasting snow pack in the Cascades (Ring and Watson, 1999).

Groundwater recharge of this nature would have provided a source of groundwater that would have maintained base flow and cooler thermal refugia as summer progressed and air temperatures increased, as well as maintaining warmer winter temperatures that would prevent or reduce the risk of anchor ice(Ring and Watson, 1999). Bansak (1998) quantified this process in a similar alluvial valley of the unregulated Middle Fork Flathead River, Montana.

Reaches associated with alluvial flood plains have been shown to be centers of biological productivity and ecological diversity in gravel bed rivers (Stanford and Ward 1988; Independent Scientific Group 1996). In the Yakima basin, bedrock constrictions between alluvial subbasins control the exchange of water between streams and the aquifer system. Under pre-development conditions, vast alluvial flood plains were connected to complex webs of braids and distributary channels. These large hydrological buffers spread and diminished peak flows, promoting infiltration of cold water into the underlying gravels. Side channels and sloughs provided a large area of edge habitat and a variety of thermal and velocity regimes. For salmon and steelhead, these side channel complexes increased productivity, carrying capacity and life history diversity by providing suitable habitat for all freshwater life stages in close physical proximity.

At a large spatial scale, each of the Yakima subbasins is conceptualized as being downwelling, or losing surface water to the hyporheic and groundwater systems at the upstream end and upwelling, or gaining surface water from the groundwater and hyporheic systems at the downstream end as described for other rivers (for example, by Stanford and Ward 1988 and Tockner and Schiemer 1997). The hyporheic zone (zone of shallow groundwater made up of downwelling surface water) extended the functional width of the alluvial flood plain and hosted a microbe- and invertebrate-based food web that augmented the food base of the ecosystem. As snowmelt-generated runoff receded through the summer, cool groundwater discharge made up an increasing proportion of streamflow. Much of this groundwater upwelled from the gravel into complex channel networks upstream of bedrock constrictions.

This upwelling is driven by the decreasing size of the sedimentary aquifers causing groundwater to move back into the river, tributaries and irrigation drains. Annual inundation and recharge also maintained the connectivity and flow of backwater, or spring brook habitats. These habitats are critical for successful completion of the life-history cycles of numerous fish species and other biota (e.g., Morgan and Hinojosa 1996; Tockner and Schiemer 1997). Historic maps and photographs indicate that these types of habitats were much more abundant prior to anthropogenic alteration of the flood plain (archive, USBR Yakima Office, Morris Uebelacker, CWU, pers. comm.)

Five distinct channel provinces are very apparent along the altitudinal gradient from source to mouth; 1) high gradient, largely constrained headwaters, 2) expansive anastomosed or braided alluvial flood plains, 3) constrained canyons, 4) meandering with expansive flood plains containing oxbows, and 5) deltaic flood plain at the confluence with the Columbia River.

Six storage reservoirs have been constructed in the Yakima Basin, including impoundment of the natural glacial lakes in the headwaters (Figure 6): Keechelus Lake (157,800 acre feet), Kachess Lake (239,000 acre feet), Cle Elum Lake (436,900 acre feet), Rimrock Lake (198,000 acre feet), Clear Lake (5,300 acre feet) and Bumping Lake (33,700 acre feet). All except Rimrock Reservoir were natural lakes prior to impoundment. Together they capture approximately one third of the annual basin-wide runoff. Storage volume equals 1.07 million-acre feet, which leaves an average of 3.86 million-acre feet of unregulated runoff annually (USBR 1983, 1999). Storage is insufficient to control all flooding. For example, flood stage discharge at Umtanum is estimated to occur on about a 5-year return interval (Chris Lynch, USBOR-YFO pers. comm.)

All of the storage reservoirs are located in the headwaters of the upper basin, within the Cascade Mountain province. The majority of the water sustaining the agricultural industry is transported to the lower basin during periods of the summer and early fall when the river would otherwise be approaching base flow. Six low-head diversion dams are located on the main stem of the Yakima, including Easton at river kilometer (rkm) 235.8, Roza (rkm 205.8), Wapato (rkm 171.5), Sunnyside (rkm 167), Prosser (rkm 75.8) and Horn Rapids (rkm 5.8). The Naches River, the largest tributary to the Yakima River, has two large diversion dams, Wapatox (rkm 27.5) and Naches Cowiche (rkm 5.8). Diversion dams are shown in Figure 6.Each of these diversion dams maintains screening structures that were installed in order to prevent upstream migration of adults or downstream entrainment by juvenile salmonids into the irrigation systems. Groundwater recharge occurs via precipitation and from the application of irrigation water, the latter of which increases recharge over pre-irrigation times by about a factor of 10 (Tom Ring, pers. comm.). Kinnison and Sceva (1963) noted that water table elevations rose substantially during the onset of irrigation in the first half of the century. Because of this, drains often were cut to reduce high water tables and prevent the development of alkaline soils. Thus, the pattern of ground water recharge has been substantially altered with post-irrigation recharge following the seasonal patterns of irrigation. Historically, recharge would have occurred mainly in the winter and spring when evapotranspiration was low and precipitation was high. The result has been a reduction in the frequency, magnitude and duration of flood plain inundation because of reservoir storage. Thus, recharge of cold, spring-melt water into the aquifer systems has been replaced by recharge of warmer water derived from irrigation later in the spring and summer.

The diversions at Sunnyside and Wapato typically divert one half of the entire river flow during the irrigation season, from May to October, while Prosser diverts 40 m 3 /s most of the year, both for irrigation and power production. Because of regulation and withdrawals for irrigation, the Yakima River experiences periods of both dewatering and elevated flows relative to the historic discharge regime (Parker and Storey 1916; Vaccaro 1986a; Conservation Advisory Group 1997; SOAC 1999; USBR 1999). For example, at Union Gap and Parker, regulation has reduced annual discharge (mean based on data from 1926-77) from 134 m 3 /s to 108 m 3 /s at Union Gap and 65 m 3 /s at Parker (Vaccaro 1986a).

Declines of this magnitude would significantly affect the processes of cut and fill avulsion that historically maintained habitat heterogeneity. Furthermore, the average annual 7-day minimum mean discharge at Parker for the same time period was 3.7 m^3/s (Vaccaro 1986a). Vaccaro (1986a) estimated that composite error of historic discharge estimates was 12% relative to the 21% change in discharge by regulation at Union Gap and the 52% change at Parker. At present, legislation calls for flows below Sunnyside and Prosser to range from 8.5 to 17 m^3/s, depending on the estimated supply of water.

Water Quality

Washington Department of Ecology has rated the Yakima River from the confluence with the Cle Elum River (rkm 481) to the mouth as having Class A, or “excellent” water quality (for detailed description, see Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A), while the American, Bumping, upper Naches and upper Yakima rivers were classified as AA, or “exceptional.” However, there are some specific water quality parameters that do not conform to this classification. For example, 72 stream and river segments throughout the Yakima Basin have been placed on the 303(d) list of threatened and impaired water bodies by Washington Department of Ecology (DOE 1996, candidate list for 1998, Federal Clean Water Act 1977). Of these segments, 83% were cited as exceeding temperature standards. Specifically, temperatures exceeded 21 ^{o}C in Yakima River and tributaries from Columbia River confluence to Cle Elum River and 16 ^{o}C in the upper Yakima, American and Bumping rivers (Figure 3).

Furthermore, standards set for DDT and DDT byproducts (including, in most cases, PCB’s and other pesticides and herbicides such as endosulfan, parathion, endrin, aldrin and dieldrin) were exceeded in 15% of the listed reaches. Six of these nine sites were located below the city of Yakima, and four of the nine were located in the Yakima River proper, ranging in distribution from Cle Elum to Horn Rapids (Figure 3). The site with greatest contamination was Horn Rapids. In essence, longitudinal linkage within the river has led to a downstream increase in contamination, with specific point sources entering from Snipes, Spring, Sulphur, Wide Hollow and Cherry creeks, and Granger and Moxee drains (however, both Snipes and Spring creeks have been removed from DOE’s draft 1998 303(d) list (Table 1). Instream flows were cited as exceeding standards set by the State in 8 of the 72 reaches, including the Yakima River near Toppenish and Horn Rapids, plus Cowiche, Wenas, Big, Taneum and Manastash creeks, and the Teanaway River.

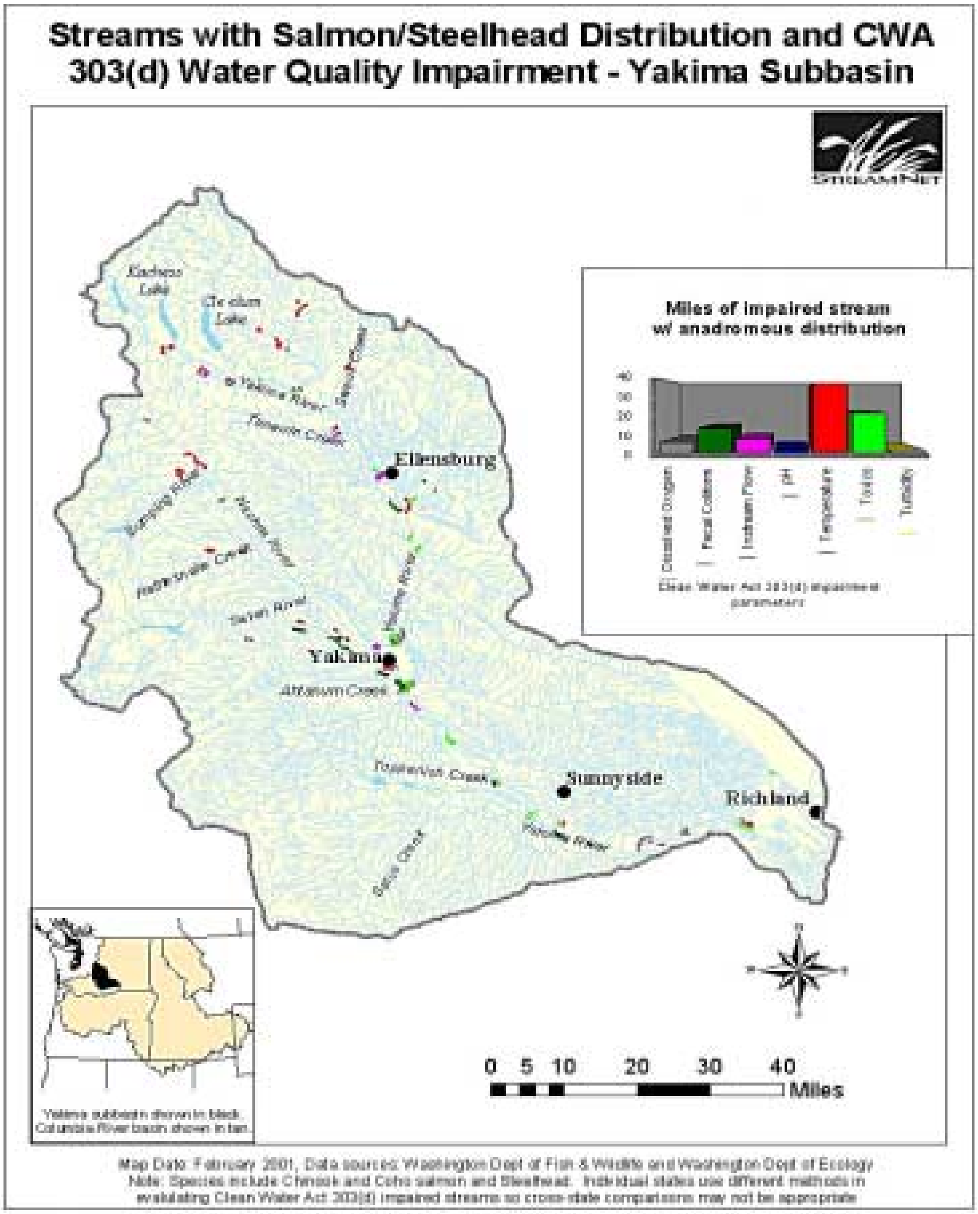


Figure 3. Streams with salmon/steelhead distribution and CWO 303(d) water quality impairment for the Yakima subbasin

Because of these listings, DOE conducted a study to determine total maximum daily load (TMDL) criteria in the lower Yakima Basin (Joy and Patterson 1997). Because the link between total suspended sediment (TSS), turbidity and concentration of DDT had previously been established (Rinella et al. 1992, 1993), turbidity standards were limited to an increase of only 5 NTU's (national turbidity units) between the confluence of the Naches and Yakima Rivers and Benton City (224 km). As discussed above, this standard was based on the State's "A" classification for this river segment. Furthermore, recommendations were made to limit tributary and drainage return concentrations to 25 NTU's (56 mg/L TSS). If implemented, this will require a 70% TSS reduction in the major drainage returns (Joy and Patterson 1997). Of particular concern are the high concentrations of DDT (and its breakdown products DDE and DDD) in fish tissue, which are among the highest concentrations recorded in the United States (Rinella et al. 1993). Subsequently, in 1993, the Department of Health recommended that people eat fewer bottom feeding fish (Joy and Patterson 1997; Washington State Department of Health 1993). This advisory is still in effect.

Table 1. Summary of water quality parameters exceeding standards set by Washington State Department of Ecology for the 303(d) list (1996)

Waterbody segment numbers are identified in parentheses.

Yakima River near Cle Elum (WA-39-1030)	Cherry Creek (WA-39-1032)	Yakima River near Roza (WA-39-1010)	Wide Hollow Creek (WA-37-1010)	Moxee Drain (WA-37-1048)	Yakima River near Toppenish (WA-37-1020)	Granger Drain (WA-37-1024)	Sulphur Creek (WA-37-1030)	Yakima River at Horn Rapids (WA-37-1010)
DDT 4,4'-DDE	Temp Dieldrin DDT 4,4'-DDE	Dieldrin DDT 4,4'-DDE	Temp Fecal Coliform Endosulphan DO Dieldrin DDT 4,4'-DDE 4,4'-DDD	Temp pH Maathion Fecal Coliform Endosulphan DO Dieldrin DDT Chlorpyrifos 4,4'-DDE 4,4'-DDD	Temp OCB-1260 Instream flow Dieldrin DDT 4,4'-DDE	Temp pH Fecal Coliform Endosulphan Do Dieldrin DDT Ammonia-N 4,4'-DDE 4,4'-DDD	Temp Endosulphan Dieldrin DDT 4,4'-DDE 4,4'-DDD	Turbidity Temp pH PCB-1260 PCB-1254 Parathion Instream flow Heptachlor Expoxide Heptachlor Fecal Coliform Endrin Endosulphan Dieldrin DDT Ammonia-N Aldrin 4,4'-DDE 4,4'-DDD

The effect of DDT, dieldrin and other pesticide contamination on river ecology is less certain. However, whole fish sampled by DOE in 1990, 1992 and 1995, found that nearly all concentrations exceeded 200 to 270 ug/kg, levels that exceed guidelines to protect wildlife populations from chronic carcinogenic risk (Joy and Patterson 1997), similar to results from earlier studies (Johnson et al. 1986). Furthermore, several studies have documented the presence of physical abnormalities on fish collected from agricultural drains and the lower Yakima River (e.g., Cuffney et al. 1997, USBR Denver Office monitoring project).

A sediment budget also was constructed for the lower Yakima, because of the link between TSS and DDT (Joy and Patterson 1997). Results indicated that in 1995, inputs from tributary and irrigation returns contributed a significant quantity of the sediment load for the river. For example, Moxee Drain contributed 35 tons/day in the latter part of the irrigation season, while the Naches River contributed only 27 tons/day, even though discharge in the Naches was 14 times greater than Moxee Drain (Table 2). TSS concentration in Granger Drain, Sulphur Creek, Spring and Snipes creeks, and combined load from the Yakama Reservation was 60, 110, 46 and 75 tons/day, respectively. These values are within the range of other studies (Fast et al. 1991). Also apparent from this analysis was the huge influx of TSS during the early part of the growing season relative to the period from July through October (Table 2) in reaches spanning the Naches confluence to Parker and Parker to Kiona. For example, mean TSS load (tons/day) from March-October was 2.4x greater than mean load calculated from July-October from the Naches to Parker (Table 2). Similar trends were apparent in the Parker to Kiona reach. Apparently, this is mainly a function of high TSS load (94 tons/day) carried by the Naches River during spring runoff (March to July) relative to July to October (27 tons/day), although increased TSS load in Yakama reservation tributaries and drains contributed to this as well. The high TSS load from the Naches is believed to be due to logging activities and sediment releases from the reservoirs (Joy and Patterson 1997). However, further studies are necessary to distinguish the importance of these sources vs. other variables, such as the influence of the "flip-flop" flow regime.

The lower reach generated 67 and 92% of the total TSS load carried from March to October and from July to October, respectively (Table 2). This indicates that the lower Yakima reach is obtaining > 90% of the TSS load during July to October from sources within this reach. Of these sources, gauged drains in project areas contributed 213 tons/day, while Yakama reservation returns cumulatively accounted for 75 tons/day, ungauged drains in project areas for 43 tons/day, and unknown sources for 55 tons/day (Table 2). Finally, as flows decreased from July through October, sedimentation became prevalent. Sedimentation in the upper reach accounted for 23% of the total TSS load (32 tons/day), while the lower basin was characterized by a 43% sedimentation rate (153 tons/day).

Numerous studies have cited temperature in the lower Yakima River, particularly below Prosser, as a serious barrier to migration and to completion of salmonid life histories (Lilga 1998; SOAC 1999; Conservation Advisory Group 1997; Vaccaro 1986b; Pearsons et al. 1996; USBR 1999). This is particularly true during the irrigation season, when temperatures are often stressful or lethal to salmonids (Lilga 1998; Lichatowich and Mobrand 1995; Lichatowich et al.1995; Fast et al. 1991) For example, Lilga found that temperatures in the lower river from June through November (1996) were lethal (>15.6 C) for salmon egg and fry incubation between 60 and 85 percent of the time. Temperatures are stressful for juveniles (>18.3 C) between 25 and 65 percent of the time and stressful for adults (>15.6 C) between 60 and 85 percent of the time. Lilga (1998) also examined the utility of using increased in-stream flows to decrease temperature in the lower river. She found that there was no relationship between mean daily summer stream temperature and flow, and that ca. 70% of the variation in water temperature was explained by air temperature. Several variables thought to influence in-stream temperatures were not measured as part of this study. These included subsurface flow from surficial aquifers, withdrawals, surface flow from tributaries and irrigation returns, channel morphology, variation in water velocity, upstream temperature conditions, solar insulation and topographic and riparian shading effects (Lilga 1998). Because of these uncertainties, Lilga concluded that a numerical model needed to be implemented before an accurate assessment could be made of the relationship between in-stream flows and temperature.

In a similar study, Vaccaro (1986b) analyzed the effect of four different management scenarios on in-stream temperatures for the 1981 irrigation season. Scenarios ranged from estimated natural conditions (e.g., no storage, diversion or return flows) to various reductions in irrigation withdrawal and return flows (e.g., 50 % reduction in all canals; 50 % reduction in the major canals—hypothetically derived from increased irrigation efficiency).

Interestingly, simulated natural conditions yielded higher in-stream temperatures in August, compared to any of the regulated scenarios. This is almost certainly a direct effect of hypolimnetic releases from four of the five storage reservoirs (all but Rimrock) (see also Vaccaro 1986b). Natural surface releases would have been relatively warmer as stratification occurred in the lakes as summer progressed. Vaccaro also found that although August temperatures were warmer, mean temperatures throughout the irrigation season were lower at Prosser and Kiona. Although many potential sources of error were noted, not included was the potential effect of groundwater inflow and the interaction between historical spring flooding and inundation of the alluvial aquifer with cool, spring melt water (as previously discussed) (Ward 1985; Bansak 1998; Ring and Watson 1999).

An analysis of the lower basin in August 1997, using digital aerial thermography indicated that there are numerous sources of cooler water entering the system from many spring brooks and some tributaries (Holroyd 1998). Influx of relatively cooler ground water likely was much greater prior to regulation—potentially providing thermal refugia for biota, including outmigrating smolts and returning adult salmon (Ring and Watson 1999). Ring and Watson (1999) concluded that the natural ability of the alluvial floodplains to moderate in-stream temperatures has been seriously compromised because of the change in the natural flow regime (as discussed previously) and because of the significant alteration and disconnection of the flood plain.

Table 2. Summary of total suspended sediment load (TSS; tons/day) in two reaches of the Yakima River

	TSS SOURCES to NACHES-PARKER REACH										TSS LOSSES from NACHES-PARKER REACH					
Month	Yakima River	Naches River	Roza return	small tribs	munic.& indust	return drains	Moxee Drain	other	Total		Wapato Canal	Sunnyside Canal	small diversions	Yakima River	sediment deposition	Total
Mar-Oct	53	94	31	1.1	1.4	2.3	31	120	334		83	58	5.3	188		334
Jul-Oct	50	27	21	1.1	1.4	2.3	35		138		79	57	5.3	29	32	138

	TSS SOURCES to PARKER-KIONA REACH									TSS LOSSES from PARKER-KIONA REACH			
			Project Areas										
Month	Yakima River	Tribal tribs & drains	gaged drains[a]	ungaged drains	munic sources	other	Subtotal w/o Yakima	Total		Irrigation Diversions	Yakima River	Sediment Deposition	Total
Mar-Oct	188	75	213	43	0.2	55	386	574		546	28		574
Jul-Oct	29	52	230	43	0.2		325	354		177	24	153	354

a. Moxee and Granger Drains, and Sulphur and Snipes Creek.
The first reach ranged from the Naches River confluence (RM 116.8) to Sunnyside Dam (RM 103.8); the second from Parker to Kiona (RM 29.9). Data based on the 1995 irrigation season and analyzed through two time spans, March-October & July-October. (Taken from Joy & Patterson 1997)

Land Ownership and Uses

The economic base of the Yakima basin is irrigated agriculture. The Yakima basin is among the leading agricultural areas in the United States. In fact, Yakima County ranks fifth in the United States in total agricultural production. In 1995, agriculture in Benton, Kittitas and Yakima counties produced an estimated crop value of $1.3 billion (Tri-County Water

Agency et al. 2000). According to the United States Department of Agriculture (USDA), in 1997 farmers in Benton, Kittitas, and Yakima counties, harvested cropland totaling 624, 000 acres (These totals include Benton County lands outside of the Yakima subbasin.)

Major crops include apples, cherries, peaches, pears, prunes, grapes, mint, grain, corn, hops, timothy hay and alfalfa. Crops produced in Kittitas County are primarily timothy and alfalfa hay, much of which is exported outside the basin. Fruit production, including tree fruits and grapes, is located primarily in Yakima County, although Benton County also has significant apple and grape production (Tri-County Water Resource Agency et al, 2000). Livestock production and forestry are also important contributors to the economic base. The major industries in the basin are related primarily to the processing of agricultural and forest products.

Patterns of land ownership within the Yakima basin are complex (Figure 4). Within the boundaries of the drainage, about 69 percent of all land is publicly owned and at least 31 percent is private (Table 3; Figure 5).

Table 3. Land ownership in the Yakima Subbasin in hectares and acres

OWNER	HECTRES	ACRES
Private	**504,560.0**	**1,246,818.0**
Unknown	**67,803.0**	**167,548.0**
US Forest Service	**361,179.0**	**892,509.0**
National Park Service	**197.0**	**487.0**
US Fish & Wildlife Service	**835.0**	**2,063.0**
Bureau of Land Management	**19,786.0**	**48,893.0**
Department of Energy	**64,788.0**	**160,098.0**
Department of Defense	**80,571.0**	**199,099.0**
Bureau of Reclamation	**60.0**	**148.0**
Washington Dept. of Fish & Wildlife	**63,418.0**	**156,712.0**
Washington State Parks	**417.0**	**1,030.0**
Washington Dept. of Natural Resources	**82,184.0**	**203,085.0**
University	**233.0**	**576.0**
County	**253.0**	**625.0**
City	**222.0**	**549.0**
Yakama Nation	**360,077.0**	**889,786.0**
Other	**60.0**	**148.0**
Total Hectares by class	**1,606,645.0**	**3,970,180.0**

More than 51 % of the public land in the Yakima Subbasin is federally owned, 35 % is tribally owned, 14 % is state-owned and the remainder is owned by local governments. Most high elevation forests are on federal, tribal and state-owned lands. Approximately 38% of the watershed is forested; these areas are generally characterized by steep topography considered unsuitable for agriculture. Most of this forestland is managed for commercial timber production. Major landowners in the forested portions of the subbasin include the Yakama Nation, USDA Forest Service, Boise Cascade, Plum Creek Timber Co., US Timberlands, Inc., WDNR, Champion International, and Burlington Northern. These forestlands are also considered suitable for grazing, and many owners currently have active grazing allotments. Additionally, WDFW owns and manages tracts in the forested portion of the subbasin for wildlife, although Boise Cascade controls the timber rights to some of those tracts.

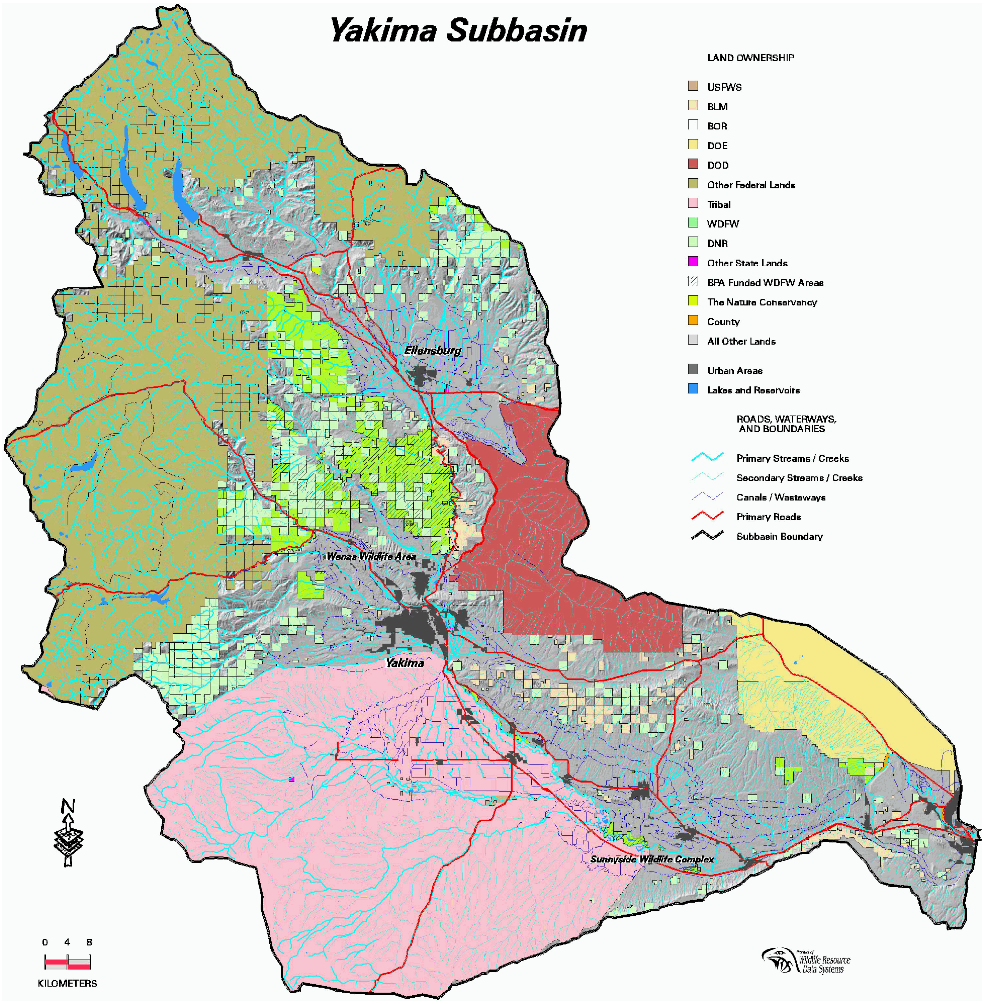


Figure 4. Current land ownership in the Yakima subbasin

Lying in the east-central portion of the subbasin, the US Army Yakima Training Center (YTC) is 323,651 acres of primarily shrub-steppe habitat. YTC is located in Kittitas and Yakima counties. and is used primarily for motorized, mechanized and armored infantry training.

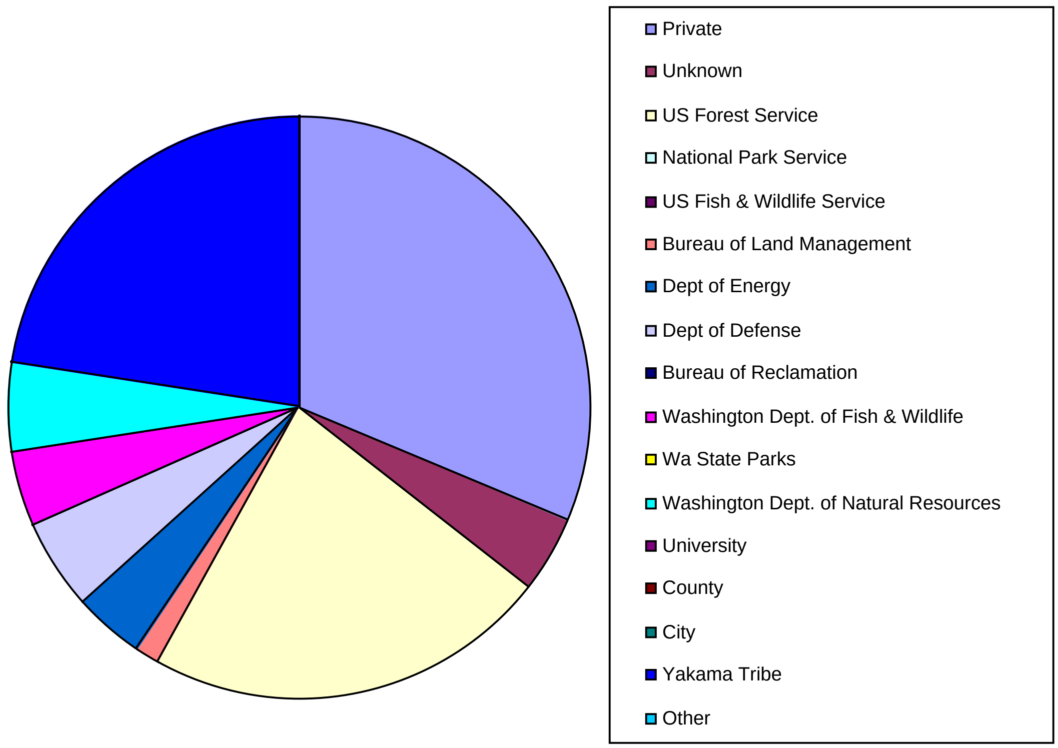


Figure 5. Land ownership in the Yakima Subbasin

The Yakama Nation Reservation in southern Yakima County comprises 25 % of the bi-county area. Most of this land is tribally owned, with only a small portion within the reservation being "deeded land." City and county ownerships are on valley floors near population centers. Privately owned lands are primarily used for agriculture, housing, commerce and industry, and are generally situated in valleys and on foothill slopes, where irrigation and transportation are accessible.

The predominant types of land use in the Yakima Subbasin include irrigated agriculture (1,000 square miles), urbanization (50 square miles), timber harvesting (2,200 square miles) and grazing (2,900 square miles). Cropland accounts for about 16 % of the total subbasin area of which 77 % is irrigated. Although the area affected by timber harvesting and grazing is roughly five times the area affected by agriculture and urbanization, the intensity of activity makes agriculture and urbanization of primary importance to water quality.

A change from row crops to hay in the Kittitas Valley has gradually occurred, and there has been a shift from row crops to permanent crops (such as grapes, apples and pears) in the lower valley. These changes affect the amount of water needed for irrigation, the methods of applying irrigation water, and the quality of water draining from fields and returning to the Yakima.

Mining, wilderness designation, and hydroelectric projects are minor land uses in the Yakima Subbasin. Floodplain gravel mining remains an intensive use. About two-thirds of the floodplain mining in Washington State has occurred along the Yakima River or the lower reaches of two of its tributaries, the Cle Elum and Naches Rivers. The Selah Pit and surrounding pits comprise the largest pit complex in the state, at more than 230 acres in

1986 (Collins. 1997). Other forms of mining are absent in the subbasin, although claims have been filed on Swauk Creek and the Cooper River, and there are large, inactive coal mining sites near Rosalyn.

Impoundments and Irrigation Projects

Six major diversion dams are on the mainstem Yakima, and several smaller dams are on the Naches (Figure 6). From uppermost to lowermost, the Yakima dams are Easton (RM 202.5), Roza (RM 127.9), Wapato (RM 106.6), Sunnyside (RM 103.8), Prosser (RM 47.1) and Horn Rapids (RM 18.0). The major dams on the Naches are Wapatox (RM 17.1) and Naches Cowiche (RM 3.6).

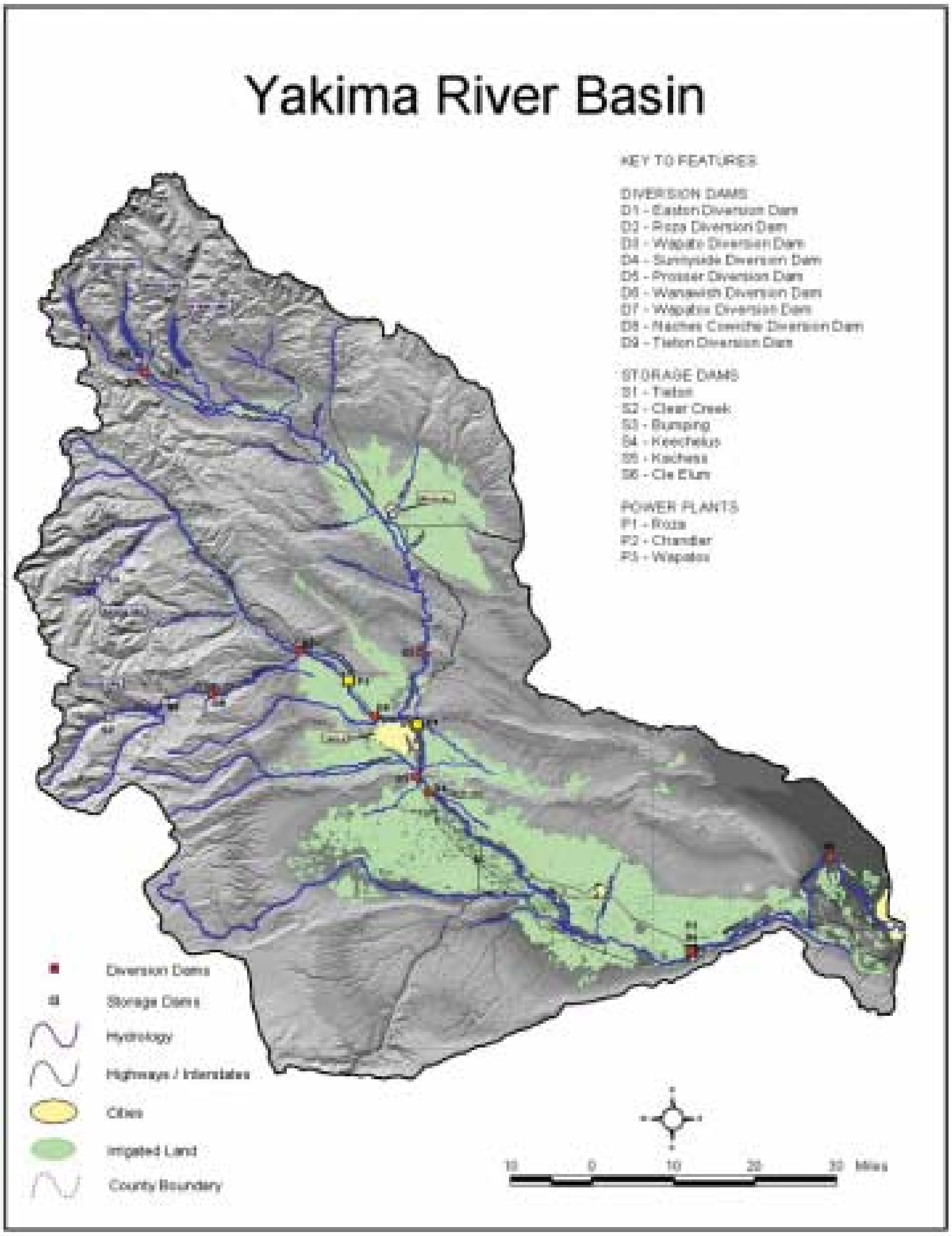


Figure 6. Yakima River Basin map showing major storage, diversion, and hydroelectric dams and irrigated lands

Three natural lakes at the headwaters of the Yakima River–Lake Cle Elum, Lake Kachess and Keechelus Lake–and one in the upper Naches drainage–Bumping Lake–have been dammed at their outlets to create irrigation storage reservoirs. An additional storage reservoir, Rimrock Lake, on the upper Tieton River in the Naches drainage, is man-made. Collectively, these five reservoirs are capable of collecting over one million acre/feet of water, almost a third of the mean annual runoff of the entire basin.

The U.S. Bureau of Reclamation (USBOR) operates most of these storage and diversion dams in the Yakima basin. The irrigable lands eligible for service under the USBOR Yakima Reclamation Project total about 465,000 acres. Of that total, the Bureau of Indian Affairs, which receives most of its water supply from the USBOR project, irrigates 136,000 acres, while private interests irrigate over 45,000 acres under separate water supply contracts with the USBOR. See Figure 6 for location of irrigated lands.

There are three small-scale hydroelectric projects, the Roza power plant, the Chandler power plant and the Naches Drop project on Wapatox Canal. In 1999 the Roza and Chandler power plants contributed about 130.4 million kilowatt hours to the federal Columbia River power system. Figure 6 is shows the basin's major storage, diversion and hydroelectric dams along with the basin's irrigated lands.

Other features of the BOR Yakima Reclamation Project include 420 miles of canals, 1,697 miles of laterals, 30 pumping plants, 144 miles of drains, plus fish passage and protection facilities constructed throughout the basin. There are other similar features operated by private entities or individuals for withdrawal of flow entitlements from the basin.

Description of Irrigation Districts

The Yakima Basin Joint Board (a partnership of irrigation districts and the city of Yakima) that promotes the multiple uses of the valley's water supply, submitted this description of the basin's irrigation system.

The Federal Yakima Project is divided in to six irrigation divisions: Kennewick, Sunnyside, Wapato, Roza, Tieton, and Kittitas, representing about 90 percent of the total water diversions in the Yakima Basin (USBR, 1999). The Wapato Division is managed by the U.S. Bureau of Indian Affairs; other divisions are managed by irrigation districts.

Kittitas Division

Kittitas Reclamation District, located in Ellensburg, Washington, operates the Kittitas Division of the Yakima Project. KRD was organized in 1911; construction of the KRD system was initiated in 1925 and completed by 1933. KRD's primary service area is the north and south sides of the Kittitas Valley, and south of the Yakima River near the towns of Easton and Cle Elum. KRD encompasses nearly 104,588 acres, however the contract KRD holds with Reclamation limits the number of irrigated acres in the KRD service area to 59,122 acres which are classified as irrigable. KRD's water right for irrigation is 336,000 acre-feet annually, provided solely by surface water diversions from the Yakima River. This water right is held by the United States, in trust for KRD and its water users. In addition, approximately 30,000 acres inside the KRD are believed to have water rights on creeks that traverse the District. Creek water rights were appropriated by individuals prior to the construction of KRD and they are not administered by KRD.

KRD is a complex system of over 330 miles of distribution facilities including canals, siphons, laterals, pumping plants, tunnels, and wasteways. Water is diverted at Easton Dam on the mainstem of the upper Yakima River (river-mile 202.5, elevation 2,170 feet). Easton Dam diverts water into the Main Canal, which can carry up to 1,320 cfs. KRD canals must cross many tributaries to the Yakima River as they carry water from Easton to the end of the canal system. In some places the original design of the canal system created passage barriers for adult or juvenile fish (Table 4).

Table 4. Canal locations and impacts.

Creek Name	*Type of Canal Facilities**	*Known Impacts of Canal Facilities*
Tucker Creek	1, 2, 3, 4	fish passage barrier
Big Creek	1,2,4	none
Little Creek	1,2,4	possible unscreened diversion
Peterson Creek	1,2,4,5	none
Spex Arth Creek	2,4	none
Tilman Creek	2,4	none
Taneum Creek	1,5,7	water delivery to creek
Manastash Creek	1,2,7	unscreened diversions
Swauk Creek	2,4	none
Dry Creek	1,2,4	none
Reecer Creek	7,8	possible barrier, unscreened diversions
Currier Creek	7,8	possible barrier, unscreened diversions
Wilson Creek	7,8	possible barrier, unscreened diversions
Naneum Creek	1,5,7,8,9	possible barrier, uscreened diversions
Coleman Creek	8	possible barrier, unscreened diversions
Cook Creek	9	possible barrier, unscreened diversions
Caribou Creek	9	possible barrier, unscreened diversions
Parke Creek	7	water delivery to creek
Badger Creek/Wipple Wasteway	7	receives operational spill from pumping plant

1. Operations and maintenance road bridge over creek.
2. Canal siphons under creek, possible fish passage barrier.
3. Concrete drop structure in creek on top of siphon.
4. Siphon drain to creek.
5. Wasteway, emergency spillway to carry 100% of canal capacity.
6. Operation and maintenance road culvert, barrier status unknown.
7. Operational spill, water delivery to creek.
8. Creek siphons under canal, possible fish passage barrier.
9. Creek overtop structure allows creek flood waters to flow in to canal. Also passes normal creek flows under canal. Possible unscreened diversion, fish passage barrier.

Roza Division

The Roza Irrigation District operates the Roza Division of the Yakima Project. RID was organized in 1920 and the district developed it's first storage contract with the USBR in 1921. The construction of RID facilities began in 1935; in 1941 irrigation water was initially applied to the district, and by 1951 most of the system was complete. Reclamation operated the district facilities until turning over operations (except the dam, power canal, and power plant) to RID in 1961. RID serves water to 72,600 acres of land along the northern rim of the Yakima Valley from near Pomona to Benton City. Water rights within the Roza Division are held by the United States government, as trustee for the RID and its water users. RID has a contract with the United States to divert up to 393,000 acre-feet of water from the Yakima River annually, but the entire water supply is subject to prorationing in water short years. Under federal contract, RID can assess from 71,000 to 73,000 acres within the district, with agriculture the dominant land use.

Roza Dam is situated on the Yakima River (river-mile 127.9, elevation 1226 feet) north of the city of Selah, Washington. The Roza Canal extends in a southeast direction for 94.8 miles, ending near Benton City. At canal-mile 10.9, water is delivered to the Roza (Table 4). Streams that intersect the Kittitas Division canal system in the upper Yakima River basin, canal facilities located at each stream, and the possible impacts of the facilities on each stream. Beyond this point the canal is reduced to carry 1,300 cfs, and is totally dedicated to irrigation service.

RID maintains six wasteways which carry return flows, operational spills, and may act as emergency spillways. In 1958 the RID and the Sunnyside Valley Irrigation District (SVID) entered into separate contracts with Reclamation to construct a system of drain channels. Operation and maintenance of the joint drains is conducted by SVID on behalf of the Sunnyside Division, which is discussed in more detail below.

Sunnyside Division

The Sunnyside Division (Division) of the Yakima Project contains thirteen entities of which, the Sunnyside Valley Irrigation District (SVID) constitutes over 80% of the total acreage. The joint use facilities are operated by the Sunnyside Valley Irrigation District. The origin of the division dates back to 1878 when the Konewock Ditch was constructed near the present day Sunnyside Dam. Initial construction of the Sunnyside Canal began in 1890 in the same location~~s~~ as the Konewock Ditch; the canal was sold to the United States Reclamation Service in 1905 and expanded until 1923 when the irrigation system for the entire Division was essentially complete.

The Division provides irrigation water to 103,570 acres of lands north and east of the Yakima River extending from Parker, just south of Union Gap to Benton City, and includes lands on the south of the Yakima river near the communities of Mabton, Grandview and Prosser. The irrigable acreage in the Division will not expand because of the acreage limitations in the individual entity contracts with Reclamation. The Division is comprised of a number of entities which hold water rights with various priority dates extending back to 1878. Overall these entities may divert up to 498,576 acre-feet per year, for irrigation, related domestic uses, and hydropower generation for pumping plants. A portion of water rights holders within the Division are subject to prorationing during water short years.

Sunnyside Canal extends over 60 miles eastward from Sunnyside Diversion Dam (river mile 103.8, elevation 900 feet). The canal has an initial capacity of 1,316 cfs. The canal delivers water to numerous entities, distribution laterals and individual irrigation deliveries. Over 3,000 delivery turnouts exist to bring water from the canals and laterals to the land. Operational spills from the Sunnyside Canal discharge to three major wasteways and in turn to the Yakima River: Zillah Wasteway (RM 89.1), Sulphur Creek Wasteway (RM 61.0), and Spring Creek Wasteway (RM 41.8).

Roza-Sunnyside Board of Joint Control

RID and the Division formed the Roza-Sunnyside Board of Joint Control in 1997. Among other things, a water quality program was established to provide baseline data and monitoring information to help the RSBOJC develop policies and programs aimed at improving water-quality conditions within its area of jurisdiction. The RSBOJC has a long-term objective of determining how management activities by the irrigation districts and land and water use practices by landowners affect water quality conditions in agricultural return flow, which, in turn, impact the quality of water returning to the lower Yakima River.

One of the RSBOJC's goals is to bring irrigation return flows into compliance with current state water-quality standards and recent Total Daily Maximum Load (TMDL) goals for suspended sediment and DDT for the lower Yakima River set by the Department of Ecology (Joy and Patterson, 1997) and affirmed by the Environmental Protection Agency. TMDLs are used by Ecology to limit the amount of a specific pollutant that can be discharged into a waterbody, thereby protecting water quality. The TMDL for turbidity in the Yakima River main stem is targeted at not more than 5 NTU increase between the confluence of the Yakima and Naches Rivers and the Kiona gage at Benton City. A 90th percentile target of 25 NTU at the mouths of all drains and tributaries within the project area by the end of the 2002 irrigation season has been set as well.

A water-quality monitoring plan was approved and implemented in the spring of 1997 to meet the goals and objectives of the RSBOJC. Water quality constituents of interest that are monitored as part of this plan include total suspended solids, turbidity, fecal coliform bacteria, total phosphorus, nitrite-plus-nitrate, and total Kjeldahl nitrogen, and in-field measurement of pH, dissolved oxygen, specific conductance, stream temperature, and stream flow (discharge). A water quality laboratory was constructed at SVID's office with the capability of running all analyses with the exception of nutrients. Currently, the USBR Pacific Northwest (PN) Regional Laboratory in Boise, Idaho is contracted for nutrient analyses.

Sites monitored as part of the current water quality program include Roza and Sunnyside Valley main canal sites, major agricultural-return flows and/or operational spillways (Granger Drain, Sulphur Creek Wasteway, Spring Creek, and Snipes Creek), and all sub-drain tributaries to the Granger Drain (located west of Sulphur Creek HUA). Sites are monitored biweekly during the irrigation season (April through October) and monthly during the non-irrigation season.

RSBOJC has developed a progressive water quality policy addressing the problems of irrigation runoff from land within its boundaries. When RSBOJC personnel observe apparent water quality violations, samples are collected and tested for turbidity. Landowners are notified of the results, and if in violation of the current turbidity target, are required to submit a compliance plan to outline their plans to correct the water quality violation.

During the 1998 irrigation season, the RSBOJC monitored discharge from private land into project waterways and recorded turbidity levels. When the sum of the NTU readings exceeded 4000 from three or fewer water samples taken no more than weekly from the same point of discharge, the landowner would be in violation of RSBOJC policy. The landowner would receive written notification and be required to begin corrective measures. During 1998, RSBOJC personnel collected 181 samples from irrigation runoff, while in the 1999 irrigation season 294 samples were collected.

A more aggressive irrigation runoff policy was adopted prior to the 1999 irrigation season in order to work toward the goal of 25 NTU by the year 2002. This policy stated that when the sum of the NTU readings exceeded 2000 from three or fewer water samples taken no more than weekly from the same point of discharge, the landowner would be in violation of RSBOJC policy. The landowner would receive written notification and be required to begin corrective measures. A short-term plan would be developed and submitted to the appropriate district within 10 days of notification, a long-term plan would be prepared and submitted before the next irrigation season.

If a landowner refused to submit a short-term plan, or if the sum of three subsequent NTU readings exceeded 2000, the irrigation water delivery would be reduced to a rate of 0.37 cfs per 40 acres until compliance was obtained or until the end of the irrigation season. If the long-term plan was not submitted, signed, and approved by the RSBOJC prior to the following irrigation season, no water would be delivered. Similarly, if a long-term plan was approved, but the sum of three or fewer NTU readings exceeded 2000, the delivery would be reduced to a rate of 0.37 cfs per 40 acres until compliance was obtained or until the end of the irrigation season. It is the RSBOJC intent to become progressively more restrictive on turbidity targets in succeeding years, with the goal of TMDL compliance.

RSBOJC is committed to the education of water users regarding the improvement of water quality in the lower Yakima River and the benefits associated with it. An understanding of the motivation behind these changes is an important step before the technical and financial aspects of the conversions are realized.

Economic factors are an indisputable consideration in the conversion to more environmentally sound irrigation practices. The RSBOJC promotes coordination among local, state, and federal programs than can provide both technical and economic assistance to landowners developing plans for environmentally favorable conversions. The National Resource Conservation Service, Washington State University Cooperative Extension, local conservation districts, and many private irrigation companies, among others, are available to assist landowners in developing effective conversion plans.

Conversion to sprinkler and drip irrigation, the elimination of tail water runoff, and the use of buffer zones or settling basins are among methods landowners are using to decrease their contribution of suspended sediment to the river. The reduction of rill and furrow irrigation leads to the use of less water, and therefore less erosion of topsoil. Lower TSS concentrations in irrigation water deliveries will lessen damage to pumps and sprinklers, particularly those in the lower basin. Micro-irrigation systems, such as sprayers, foggers, drip, and trickle irrigation require less filtration to prevent clogging due to the presence of suspended sediment. Additionally, less sediment in district waterways will benefit the irrigation districts by reducing the time and money allocated for dredging drains and canals, and on vegetation control.

Tieton Division

The Tieton Division of the Yakima Project is managed by the Yakima-Tieton Irrigation District (YTID). Tieton Diversion dam was completed in 1908 and water was first delivered through the main canal in 1910. The district provides water to 27,900 acres of land west of the City of Yakima, extending from the West Valley area to the Town of Tieton. YTID has contracts with the United States to divert up to 114,000 acre-feet of water, although a portion of the water supply is subject to prorationing in water short years. In 1986 YTID completed a Rehabilitation and Betterment Project at a cost of $78 million, converting nearly all of the original open canal system in to a pressurized pipeline delivery system.

YTID diverts water at the Tieton Diversion dam (river-mile 14.2, elevation 2282 feet), located on the Tieton River, downstream from Rimrock Reservoir. The Tieton Canal (the only remaining open canal in the distribution system) extends 12 miles from the dam to French Canyon re-regulating reservoir. French Canyon reservoir, situated on the North Fork of Cowiche Creek, has a 550 acre-feet capacity. Because of the closed, pressurized irrigation system, YTID can deliver water on demand. The re-regulating reservoir is necessary to allow for fluctuations in water use and to manage water efficiently. The reservoir also creates head to pressurize the water delivery system.

From French Canyon reservoir YTID distributes water through over 200 miles of buried pipeline to 2,000 turnouts. Six pumping stations maintain pressure in the pipeline system. In addition, YTID also operates Cowiche and Orchard Avenue Hydropower plants under FERC License No. 7337 and 7338 and state DOE Permit No. 256. These plants have a combined capacity to produce 3 megawatts of electricity, and they serve as pressure-reducing stations for the pipeline distribution system.

Kennewick Division

The Kennewick Division is operated by the Kennewick Irrigation District (KID), located in Benton County, Washington. KID was organized in 1917, and the Kennewick Division of the Yakima Project was authorized by Congress in 1948. Construction of the district was completed in 1957. KID encompasses portions of the cities of West Richland, Richland, and Kennewick.

KID serves approximately 20,200 acres, of which 14,900 acres are agricultural and 5,300 acres are residential. Urban development within the KID is significant, and the district now serves 586 agricultural accounts and 15,214 residential accounts. Although the District boundary encompasses 55,000 acres of land, water is only delivered to 20,200 acres which are classified as irrigable. The 28,559 acres within the district which are classified as non-irrigable or dry, are not assessed, and do not have water rights. An additional 6,300 acres in the district are classified as irrigable and authorized for development, but irrigation service to these lands has not been developed. KID has a contract with the United States dated July 22, 1953 to divert up to 109,275 acre-feet of water from the Yakima River annually. The annual diversion claimed for power for pumping is 136,594 acre feet; the combined total diversion is 245,869 acre feet.

KID’s water is diverted at Prosser Dam (river mile 47.1, elevation 633 feet) into the Chandler Power Canal which has a capacity of 1500 cfs, and is conveyed 11 miles to the Chandler Power and Pumping Plant to: (1) meet the irrigation demands of KID; and (2) operate the two hydraulic turbines which pump water through a pipeline that passes beneath the Yakima River to the Main Kennewick Canal.

The Main Canal has a capacity of 330 cfs and extends for about 24 miles to the Amon Siphon and Wasteway. The Amon Wasteway leads to the confluence of the Yakima and Columbia Rivers. KID does not maintain drains or a drainage network and contributes no significant surface return flow to the Yakima River other than Amon Wasteway..

Effects of Irrigation Division Operations

Operation of the irrigation divisions of the Yakima Project results in the return of significant volumes of water to the Yakima River after it has been diverted for irrigated agriculture (flow volumes in the river are managed by the US Bureau of Reclamation and are not discussed here). Return flows affect the hydrology of ground water and surface water in the Yakima River basin. During summer and fall, return flows contribute to the flow of the Yakima River in certain reaches, including a number of tributaries (Rinella et al. 1992). Return flows also affect the hydrology of ground water and surface water. Return flows affect water quality in the Yakima River and tributaries (Joy and Patterson 1997; Morace et al., 1999). Salmonid fish are known to inhabit some return flow facilities and natural tributaries which receive return flows (WDF and WDW 1993). In some cases hundreds of adult salmon have been falsely attracted to irrigation wasteways where spawning and rearing conditions may be unsuitable.

Water Quality Effects of Return Flows

Several reaches of the Yakima River and some tributaries do not satisfy Washington State water quality standards for numerous parameters. Wastes from some agricultural practices, irrigation return drains, municipal and industrial treatment plant effluents, runoff from forest and range land, and urban runoff have been identified as pollutant sources. Surface irrigation return flows may carry high levels of suspended sediment, pesticides, nutrients, bacteria and oxygen demanding substances, while subsurface return flows may carry pesticides and nutrients (Joy and Patterson 1997). Return flows can measurably affect water quality in the Yakima River, particularly in the lower Yakima Valley, where agricultural return drains, and tributaries with agricultural drainage, comprise a major portion (50% - 80%) of total river flow during July to September (Rinella et al. 1992; Joy and Patterson 1997).

The U.S. Geological Survey (USGS) investigated the water quality conditions of the Yakima River Basin, including long-term trends in water quality, historical conditions, and trends associated with natural and human induced factors. USGS reported that state standards were not met for stream temperature, pH, and fecal-coliform bacteria in most tributaries to the lower Yakima River during the irrigation season. Additionally, they reported phosphorus and nitrogen (nitrite-plus-nitrate) concentrations and turbidity were commonly detected at levels making them of concern to eutrophication and aquatic plant growth (Rinella et al. 1992). Overall, suspended-sediment, turbidity, nutrient, biological, and pesticide contamination have been attributed to the impairment of beneficial uses (domestic water supply, primary and secondary contact recreation, aesthetic enjoyment, and support of fish and wildlife). The quality of water returning to the Yakima River main stem and its tributaries from agricultural return flows has not always been supportive of these beneficial uses.

In 1995, whole water samples were analyzed for 46 pesticides at Granger Drain, Spring Creek, Sulphur Creek, and the Yakima River at Euclid Bridge as part of the WDOE's TMDL evaluation. Organochlorine, organophosphate, and nitrogen-containing pesticides were frequently detected at all sites. Total DDT was detected above the human health and aquatic life chronic toxicity criteria at all sites on three or more sampling dates. One sample collected at Granger Drain contained twice the previous high concentration of t-DDT detected since 1968 (Joy and Patterson, 1997).

The movement of suspended sediment in streams is an important factor in the transport and fate of chemicals in the environment. Many water-quality constituents including trace metals, organic compounds, indicator bacteria, and nutrients are associated with suspended sediment. Recent studies have identified a strong relationship between concentrations of DDT and suspended sediment in the Yakima River and tributaries draining agricultural lands. This finding suggests that DDT transport to the Yakima River can be effectively controlled by measures that reduce erosion of agricultural soils and limit sediment transport (Joy and Patterson 1997).

Figure 7 and 8 show the turbidity of water diverted from the Yakima River into the Roza and Sunnyside diversions in 1998-99, and the turbidity of the canal at locations throughout the irrigation system. NTU turbidity values for the diversions ranged from 11-30 NTU in 1998-99 . In comparison, major return flow drains (Granger Drain, Sulphur, Spring, and Snipes creeks) from the Roza and Sunnyside divisions had NTU turbidity values ranging from 21-136 NTU where they returned water to the Yakima River (Figure 9), a significant increase in turbidity. By combining the flow of each drain with the levels of turbidity observed, it was calculated that the drains discharge from 2-152 tons per day of sediment to the Yakima River (Figure 10). The reduced water quality of return flows has been associated with the impairment of biological communities of fish, invertebrates, and algae in return drains and portions of the mainstem Yakima River (Morace et al. 1999).

In order to limit the transport of sediment and pesticides to the Yakima River, a goal of the Roza-Sunnyside Board of Joint Control's (RSBOJC) is to bring irrigation return flows into compliance with current state water-quality standards and recent Total Daily Maximum Load (TMDL) goals for the lower Yakima River set by the Department of Ecology (Joy and Patterson, 1997) and Environmental Protection Agency under the Clean Water Act. Table 5 shows turbidity values recorded in 1994 and 1995, before the RSBOJC implemented their water quality program. The RSBOJC adopted the TMDL target turbidity goal of 25 NTU as a water quality goal for project waterways within its area of jurisdiction. All irrigation runoff discharged to project waterways either directly or indirectly from lands within RSBOJC boundaries must comply with the water quality goal established by the RSBOJC (see RSBOJC Policies for detailed monitoring and compliance plans) by the year 2002.

Figures 7 and 8 show the effects of the RSBOJC water quality program, which was implemented in 1997. The water quality program has resulted in significant improvements in the quality of water being returned to the Yakima River. In Granger Drain, turbidities have been reduced 50% from historic levels, and progress has been observed in Sulphur Creek. As water quality conditions of return flows to the Yakima River improve due to the RSBOJC efforts, adverse effects to aquatic resources will diminish.

Water quality standards are generally met in the mainstem upper Yakima River, although some tributary streams are affected by return flows. A comparison was conducted of the Yakima River at Ellensburg with three Kittitas Valley tributaries: Cherry Creek, Wilson Creek, and Wippel Wasteway. The return flows were significantly higher in nutrients, suspended sediment, and fecal coliform bacteria than the mainstem Yakima River. Pesticide concentrations in stream bed sediments which carry return flows were also elevated when compared to background conditions (Tables 6 and 7).

Table 5. Ten percent exceedence levels for total suspended solids (TSS) in selected drains of the Roza-Sunnyside project area in 1994 and 1995

Standards are compared to Clean Water Act and TMDL standards, and estimated percent reductions in TSS necessary to meet those standards.. Modified from Joy and Patterson, 1997.

TRIBUTARY	TURBIDITY GOAL	TSS GOAL mg/L	TSS (10% Exceedance Level)[1] mg/L		PERCENT REDUCTION NEEDED	
			1994	1995	1994	1995
Moxee Drain	25 NTU	56	343	285	84	80
Granger Drain	25 NTU	56	408	748	86	93
Sulphur Ck.	25 NTU	56	57	215	2	74
Spring Ck.	25 NTU	56	45	299	0	81
Snipes Ck.	25 NTU	56	10	64	0	13

[1] 10% of the samples exceeded these levels

Table 6. Median water quality values (range in parentheses) from the mainstem Yakima River and major irrigated agriculture return flows in the Kittitas Valley

Adapted from Bain, Jr. 1999

PARAMETER	**YAKIMA RIVER AT ELLENSBURG**	**CHERRY CREEK**	**WILSON CREEK**	**WIPPEL WASTEWAY**
pH	7.5 (7.2-7.9)	7.9 (7.5-8.3)	7.7 (7.4-8.8)	7.9 (7.5-8.4)
specific conductance micro siemens/cm	89 (63-125)	301 (177-399)	201 (131-261)	330 (172-523)
dissolved oxygen mg/l	10.7 (8.1-13.4)	--	11.4 (8.0-14.3)	--
suspended sediment mg/l	6 (<1-133)	30 (4-233)	12 (2-134)	24 (1-117)
total phosphorus mg/l	.03 (.01-.28)	.21 (.10-.49)	.12 (.05-.51)	.21 (.11-.49)
ammonia mg/l	.02 (<.01-.11)	.02 (<.01-.13)	.02 (<.01-.11)	.02 (<.01-.11)
nitrite/nitrate mg/l	.06 (<.01-.58)	.94 (.04-2.8)	.25 (.03-.64)	.96 (.11-4.7)
fecal coliform colonies/100 ml	2 (1-30)	1100 (240-3300)	700 (79-1300)	1300 (350-3300)

Table 7. Concentrations of selected pesticides from bed sediments of Cherry Creek

Cherry Creek is a Kittitas County stream which carries agriculture return flows, compared to Cle Elum River bed sediments which represent background conditions. All data are in micrograms per kilogram; the Cherry Creek samples were replicates. Adapted from Bain, Jr. 1999.

LOCATION	CHLORDANE	DIELDRIN	DDD	DDE	DDT
Cle Elum River	<1	<0.1	<0.1	<0.1	<0.1
Cherry Creek	9	35	9	30	15
Cherry Creek	10	39	13	28	28

Effects of water quality on fish

Pesticides carried to the Yakima River by return flows enter the aquatic food web and become incorporated into fish tissue. WDOE has issued a health advisory warning, which states that eating large amounts of resident fish (suckers, carp, bass) from the lower Yakima River may increase an individual's risk of cancer. However, anadromous salmonids have substantially lower concentrations of pesticides in their tissues than resident fish species, and for all species the observed concentrations have been below threshold levels that could affect reproductive success (e.g. hatching success, fry mortality). The low levels of pesticide concentrations in salmon can be explained by the short freshwater residence time and distribution of those species in the Yakima Basin (Johnson et al. 1986). Pesticide concentrations in fish and water tend to increase with progression downstream in the Yakima Basin.

Steelhead spawning and early rearing generally occurs in the upper reaches of tributary streams or the mainstem Yakima River; water quality of return flows is not expected to affect these life-stages. Adult steelhead are found throughout the lower reaches of the Yakima Basin in the late fall and winter. Adults hold in the river between Prosser and Sunnyside dams until they move upstream to their spawning habitat (Hockersmith et al 1995). hey are not likely to be adversely affected by return flows, which are greatly diminished following the irrigation season (CH2M Hill 1998).

Juvenile steelhead rearing in drains, tributaries, and the mainstem Yakima River are likely to be adversely affected by the water quality conditions of return flows. Morace et al. (1999) reported that in a survey conducted in 1991, severe impairment of the fish community in Granger Drain was associated with high levels of pesticides in fish tissues and the presence of external lesions on the bodies of fishes. Mainstem river sites in the lower Yakima River also displayed impairment of biological communities associated with increasing intensity of agriculture (Cuffney et al. 1997; Morace et al. 1999). Anecdotal reports of juvenile *O. mykiss* inhabiting the drains exist, but a comprehensive survey of fish use of the return flow drainage network has not been conducted.

Bull trout spawning and early rearing occurs in the upper reaches of the basin, where irrigated agriculture return flows are not present, and they are considered unlikely to be affected by irrigation return flows. Migratory bull trout might be expected to avoiding seasonally warm temperatures in the lower basin when water quality conditions are poorest. Pesticide concentrations in water tend to be highest in the late summer, when mainstem river flows are lowest and return flows make up a significant portion of the base flow of the river (Johnson et al. 1986; Joy and Patterson 1997).

Water Temperature Effects of Return Flows

Yakima River temperatures respond to factors similar to many rivers, including solar radiation, elevation, air temperature, flow volumes, tributary and irrigation return flow volumes and temperatures, riparian and topographic shading, surface and groundwater interactions, and reservoir operations (Bartholow 1989; Lilga 1998).

During the summer, temperatures of the lower Yakima River and many tributaries (even at higher elevations) can frequently exceed levels suitable for salmonids (Rinella et al. 1992). Air temperature is the most important variable affecting Yakima River temperature, and its relative influence increases with progression from upstream to downstream (Vaccaro 1986).

The United States Geological Survey, in cooperation with the Yakama Nation, developed a water temperature model to determine the effects of irrigation return flows on water temperatures of the lower Yakima River (Vaccaro 1986). This modeling study examined the effects of (1) a basin-wide 50% reduction in return flows, and (2) a 50% reduction of return flows entering the lower Yakima River below Parker. Under neither scenario were water temperatures effectively reduced in the lower Yakima River. At the time of the year when water temperatures become unsuitable for salmonids, major return flows are generally cooler than the Yakima River at the point of return. This is because return flow facilities collect and discharge both surface water as well as subsurface water, which is cooler than surface water in summer (Vaccaro 1986). Relatively cool return flows may produce localized pockets of lower temperature water where they enter the main river.

Fish Use of Facilities and Streams with Return Flow

At their confluence with the Yakima River, some irrigation return flow facilities may also produce a *false attraction* for adult salmon or steelhead on their way to upriver spawning areas. False attractions occur when adult or juvenile fish migrate from the river into a man-made irrigation return flow facility such as a drain or a wasteway where suitable habitat does not exist. Irrigation districts in cooperation with Reclamation have just initiated studies of this phenomenon.

For example, fall chinook and coho salmon spawners were observed at the mouth of Spring Creek drain near Whitstran, following the irrigation season (Cuffney et al. 1997). False attraction was also documented at the Columbia Irrigation District return flow wasteway at Columbia Park near Kennewick, Washington, where adult steelhead, coho and fall chinook were observed to congregate and attempt to spawn (John Easterbrooks, WDFW, Yakima, personal communication). That wasteway was subsequently screened to prevent adult salmonids from entering the facility.

In 1999 and 2000 large numbers of adult coho salmon were observed congregating in Sulphur Creek Wasteway (Table 8). In contrast, only a few steelhead and fall chinook salmon have been observed. Fish may be attracted to the wasteway in large numbers because they are falsely attracted to Roza Canal water, which originates in the upper Yakima River. Other factors which may contribute to the false attraction include hatchery operations, which acclimated coho smolts in the Roza Canal through spring of 1998, and hatchery rearing practices, which rear fish to smolt stage in the lower river, then acclimate smolts in the upper Yakima River. Finally, some natural reproduction may be occurring in the wasteways. These questions are current topics of study.

Table 8. Summary of spawning survey data collected for selected drainages managed by the Roza-Sunnyside Board of Joint Control [1]

Site	Reach	Redds	Carcasses	Live Fish
Sulphur Ck 11/21/00				
	Tear-Allan Rd	34	25	2
	Allan-Sheller Rd	57	139	2
	totals	*91*	*164*	*4*
Snipes Ck 11/30/00				
	Mouth-Railroad	52	5	4
	Railroad-Benton Canal	17	4	1
	totals	*69*	*9*	*5*

[1] Snipes Ck includes lower Spring Ck. Carcasses and live fish were predominantly coho salmon, although 1 fall chinook carcass was found in Snipes Creek. Earlier surveys identified 4 fall chinook carcasses in Sulphur Creek. (Table is by Patrick A. Monk from unpublished data.)

Steelhead trout may, in some cases, inhabit man-made irrigation return flow facilities. One post-irrigation season survey showed *Oncorhynchus mykiss* (unconfirmed as to resident rainbow or steelhead trout parentage) to be present at 3 of 4 study sites in the lower reaches of agricultural drains (Cuffney et al. 1997; unpublished USGS file data). Two radio-tagged steelhead, 1.9% of the tagged sample, were observed to spawn in Marion Drain (Hockersmith et al. 1995). Steelhead also inhabit tributaries such as Toppenish Creek and Cherry Creek (Pearsons et al. 1994) where irrigation return flows can be intermingled with natural flows. In these latter cases, return flows would increase summer base flow but would also tend to reduce water quality (Joy and Patterson 1997). Little information has been collected to determine the impacts of return flows on steelhead habitat in natural tributaries, or to define the extent of false attractions to return flow facilities. Available temperature data (Vaccaro 1986) would suggest that during summer the more significant irrigation return drains may, at their point of entry to the lower Yakima River, provide an area of improved temperature conditions for salmonid fish, although poor water quality is still of concern (Morace et al. 1999).

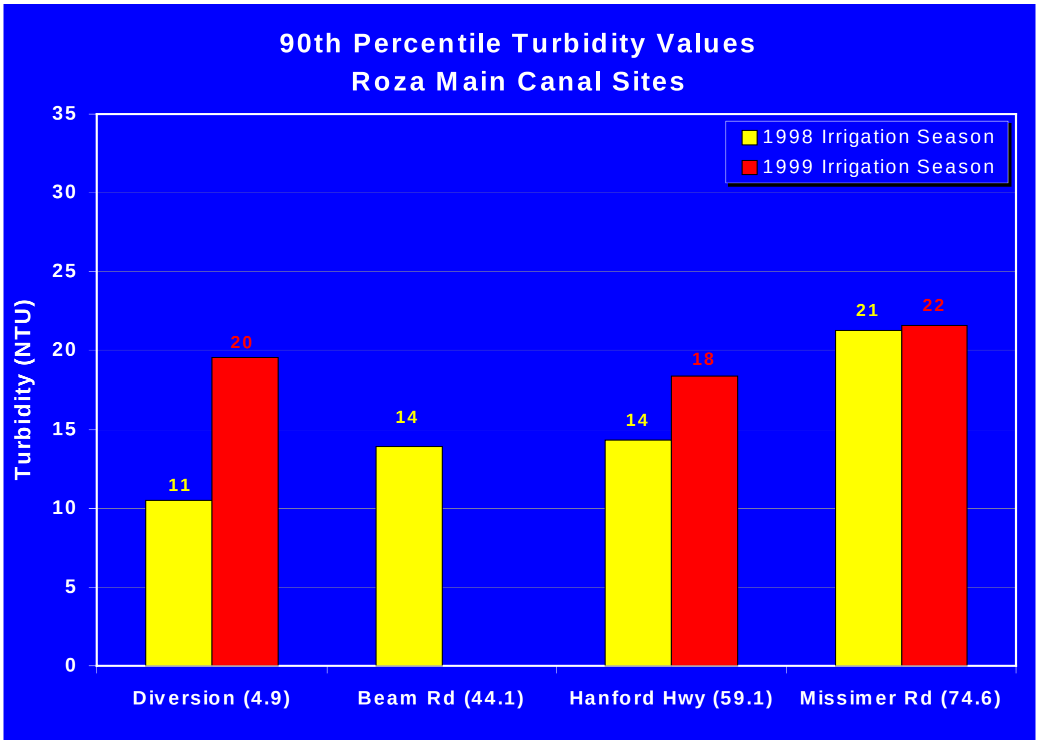


Figure 7. Turbidity of water diverted into the Roza Main Canal, and the turbidity as canal water progresses downstream through the system (RSBOJC, unpublished data)

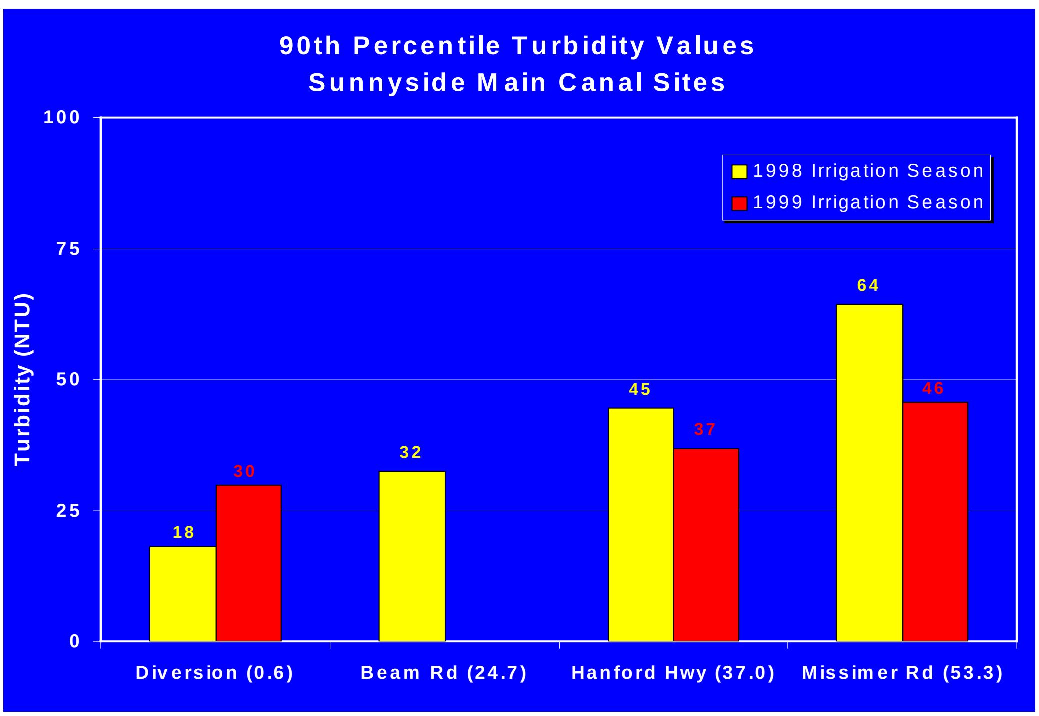


Figure 8. Turbidity of water diverted from the Yakima River into the Sunnyside Main Canal, and turbidity as the canal water progresses downstream through the system (RSBOJC, unpublished data)

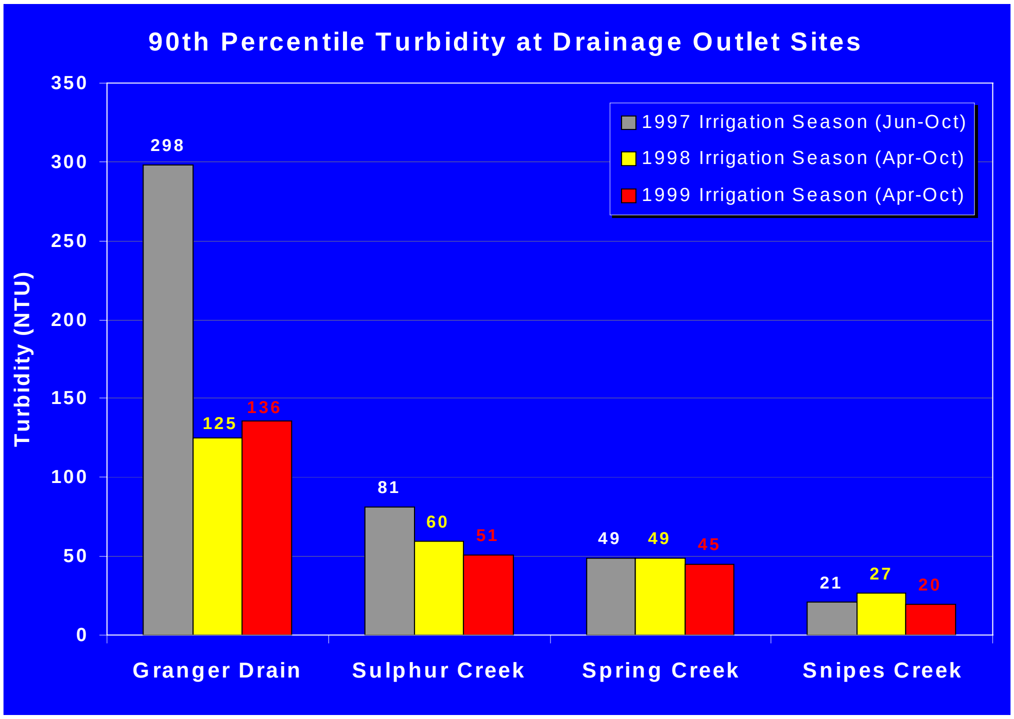


Figure 9. Recent trends in water quality for major irrigation return flow drains in the Roza and Sunnyside divisions of the Yakima Project (RSBOJC, unpublished data)

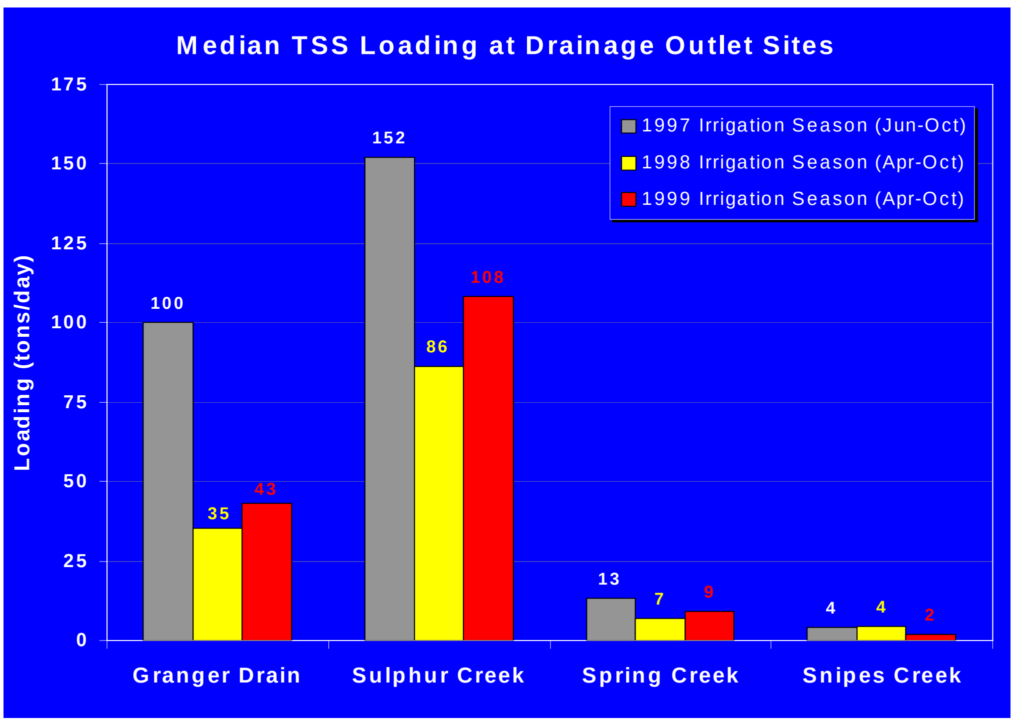


Figure 10. Sediment loading measured in tons of sediment per day to the Yakima River during the irrigation season from major return flow drains in the Roza and Sunnyside divisions (RSBOJC, unpublished data)

Protected Areas

Federal

Approximately 7.3 percent (about 450 square miles) of the subbasin lies within four federal wilderness areas. The USDA Forest Service manages the Cle Elum and Naches Ranger Districts of the Wenatchee National Forests that contain about 340,000 protected acres of designated wilderness: the William O. Douglas Wilderness Area (Bumping River drainage), the Alpine Lakes Wilderness Area (Waptus River drainage), the Goat Rocks Wilderness Area (North and South Fork Tieton River drainage), and the Norse Peak Wilderness Area (Little Naches drainage. The BLM manages portions of their lands in "protected areas." In addition, under the 1994 "President's Forest Plan," several thousand acres on these ranger districts are in Late Seral Reserve status, where there are no planned timber harvests. Unfortunately, because all of the habitat would otherwise be excellent, all of the area within the Alpine Lakes and Goat Rocks wilderness areas lies above impassable dams and is inaccessible to anadromous fish.

The Toppenish National Wildlife Refuge, managed by the USDI Fish and Wildlife Service, is located along Toppenish Creek near Toppenish. It contains riparian and wetland plant communities, and supplies habitat for many thousands of migratory waterfowl. Many other species including many migratory raptors and passerines, utilize this refuge.

Protected areas on the US Army YTC include a 40,000-acre area managed for restoration of sage grouse habitat. This area also includes seasonal restrictions on the timing and use of training activities. Additionally, localized areas are buffered for the protection of riparian areas, rare plant sites, hawk/eagle nests and cultural resources.

Yakama Nation

The Yakama Nation Forest Management Plan provides for Land Use Management Areas (LUMA's) within the forested areas of the reservation. Special LUMA's dedicated to non-timber uses and protection of resources include dispersed Old Growth Reserves, and Riparian and Watershed Reserves. The Yakama Nation also manages areas such as the Wapato Wildlife Area and Satus Wildlife Recreation Area for wildlife.

State of Washington

Washington Department of Natural Resources

The Washington Department of Natural Resources manages the 64-acre Selah Cliffs Natural Area Preserve in the Yakima canyon.

Washington Department of Fish and Wildlife

Wenas Wildlife Area

The 105,222-acre Wenas Wildlife Area, located in Yakima and Kittitas Counties on the extreme western edge of the Columbia Plateau which gains elevation westward toward the Cascade Mountain Range (Figures 4 and 76). The Area was created in 1997 by combining the Wenas and Cleman Mountain Units from the Oak Creek Wildlife Area with the South L.T. Murray Unit formerly part of the L.T. Murray Wildlife Area. The entire Wenas Wildlife Area lies within the Yakima Subbasin and is comprised of lands owned by WDFW, Washington State Department of Natural Resources, and the Bureau of Land Management. The following four management units comprise the Wenas Wildlife Area: 31,050 acres in North Cleman Mountain; 35,221 acres in South Umtanum Ridge; 12,852 acres in Roza Creek; and 26,099 acres in Umtanum Creek.

The Wenas Wildlife Area provides winter range for Rocky Mountain elk and supports Rocky Mountain mule deer, big horn sheep, sage grouse and a myriad of small mammals, neotropical/upland birds, raptors and reptiles. The North Cleman Mountain Unit contains forestlands and historically farmed agricultural valleys. Wenas Creek flows through braided channels for approximately one mile within the Cleman Mountain Unit. This fish-bearing stream continues through the Wenas Valley and empties into the Yakima River thus impacting anadromous fish habitat quality with the Yakima River Basin. Boise Cascade Corporation maintains the timber rights (WDFW did not obtain timber rights when these land were purchased in the 1950s). Most of the merchantable timber was cut from the lands acquired by WDFW for the Wenas wildlife Area prior to acquisition. At this time, timber harvest is not planned for parcels on which WDFW owns the timber rights.

The South Umtanum Ridge Unit forms the south slope of Umtanum Ridge. The elevation climbs from 1,600 feet at the base of the ridge to 4,060 feet at the highest point. Intermittent streams such as Cottonwood Creek punctuate the landscape. Originating in canyons and draws, intermittent streams flow south into Wenas Creek. There are also numerous perennial springs scattered throughout the Unit. It predominately contains shrub-steppe vegetation.

The Roza Creek Unit encompasses the watershed lying between North and South Umtanum Ridge. Elevation on the Unit ranges from 1,200 feet at the Yakima River to over 3,600 feet at the top of the ridges. Roza Creek is a small perennial, fish-bearing stream that flows approximately four miles in a southeasterly direction into the Yakima River. Bordered by steep slopes and ridges on both sides, the creek bottom supports a narrow band of riparian habitat throughout its length.

The Umtanum Creek Unit encompasses approximately 75% of the entire Umtanum Creek watershed. Elevation ranges from 1,400 feet at the Yakima River to just over 4,000 feet at the ridge summit. Umtanum Creek runs for ten miles through the Unit and empties into the Yakima River. Steep basaltic cliffs rise on both sides of the steam corridor. The narrow riparian forest zone adjacent to Umtanum Creek is comprised of ponderosa pine, Douglas fir, black cottonwood, aspen, and willows. On uplands on the north-facing slope of Umtanum Ridge, past range fires have created a unique mosaic of grassland and shrub land habitats that are interspersed throughout the north-facing slope. The south-facing side of Umtanum Ridge is very dry, which is characteristic of south-facing exposures in this area. In 1972 WDFW relocated eight California big horn sheep at the mouth of Umtanum Creek. Today there are close to 200 big horn sheep forming one of the largest bands in the state.

Sunnyside Wildlife Area

The Washington Department of Fish and Wildlife owns and manages the Sunnyside Wildlife Area, which encompasses approximately 4,265 hectares (10,538 acres) along the Yakima River floodplain in the lower Yakima Valley and along the Rattlesnake Ridge north of Prosser and Benton City (Figure 4). The Sunnyside Wildlife Area is comprised of the following five main units: the 2,786 acres at Sunnyside Unit; the 980 acres at the I-82 Unit; the 1,031 acres at Byron Unit; the 3,661 acres at Rattlesnake Slope Unit; and the 2,080 acres at Thornton Unit.

The Sunnyside Unit is located in one of the state's most productive farming areas. Situated on the Yakima River floodplain, the Unit contains approximately 13 miles of Yakima River frontage and rare cottonwood gallery forest riparian habitat. Cover types include: riparian forest, riparian shrub, lacustrine, palustrine, riparian shrubscrub, island, grassland, shrubland, shrubscrub, agriculture, and urban. Six wetlands occur on this unit varying in size from 15 to 100 surface acres. Two of these lakes are located on the Snipes segment, which is designated as a waterfowl reserve and has the potential of holding 20,000 to 30,000 wintering waterfowl.

The Byron Unit contains a series of depressions and rolling hills approximately 5 miles south of Grandview. A major drain carrying ground water and irrigation water runs through the area creating a series of ponds extending approximately two miles and nearly 400 surface acres in size. Byron Unit is punctuated by numerous ephemeral wetlands and permanent ponds that provide waterfowl brood rearing habitat, while upland habitats include both grasslands and shrublands. Cover types include grassland, shrubgrass, riparian shrubscrub, palustrine, lacustrine, island, agriculture, and urban.

The I-82 Unit is made up of 17 separate parcels of property lying along the Yakima River and Interstate 82 from Union Gap to Zillah. The unit offers scatter public access to the Yakima River and nearby ponds, and is adjacent to the primary highway and railroad transportation corridors through the region. The riparian habitat along the river, sloughs, and ponds provides excellent waterfowl and upland bird nesting, brooding and winter habitat. Upland habitat consists of open areas that were formerly agricultural fields and orchards

The Rattlesnake Slope Unit lies on the eastern end of Rattlesnake Ridge in Benton County. It is bordered by the top of Rattlesnake Ridge on the southwest, Highway 225 and the Yakima River on the southeast, and the portion of the Hanford Site that was recently designated a National Monument on the north. The terrain is gently rolling with abrupt inclines on the west side and on the immediate slopes of Rattlesnake Hills. The Unit is comprised largely of bluebunch wheatgrass and other native perennial bunchgrasses along with scattered patches of sagebrush and cheatgrass. This Unit provides critical habitat for shrubsteppe obligate species such as sage grouse and other wildlife species including T&E and PHS assemblages.

The Thornton Unit contains remnant shrub-steppe habitat and historic wheat fields that have been returned to shrub-steppe. The Unit is located approximately 16 kilometers (10 miles) north of Prosser, Washington and 3 miles southwest of the Rattlesnake Slope Unit. Soils range from bare rock to over three feet deep, allowing for the establishment of sagebrush stands, grasses, and forbs. Steep canyons bottom out at just under 1,500 feet in the southern most part of this area while ridge top elevations extend to 2,400 feet on the north side of the unit.

Oak Creek Wildlife Area

The Oak Creek Wildlife Area is located in the Yakima River basin comprising approximately 89,000 acres of owned or leased lands situated between the Tieton River and the Wenas Valley and bisected by the Naches River. The original acquisitions and subsequent purchases of additional property were undertaken by the then Washington Department of Game to provide critical winter range for expanding population of big game, primarily Rocky Mountain elk. The area also currently provides habitat for a herd of California bighorn sheep that were reintroduced in 1967.

Located on the east slopes of the Cascade Mountains, topography and vegetation vary considerably over the various geographic units that make up the Oak Creek Wildlife Area. Many of the open ridges and south slopes support big sagebrush, bitterbrush, and rabbitbrush, whereas the higher elevations and north slopes support Ponderosa pine, Douglas fir, and white fir. The most prevalent native perennial grass across most of the area is bluebunch wheatgrass. A large component of Oregon white oak is found in the riparian zones and adjacent lower canyons of the Tieton River and Oak and Cowiche creeks.

Snake River Wildlife Mitigation Properties

The following properties were purchased with ratepayer funds to mitigate for losses to riparian habitat resulting from development of the Snake River hydropower system. They are currently managed by the WDFW. Sulphur Creek contains 88 acres and was purchased in January 1994; Whitstran contains 21.6 acres and was purchased in November 1993; Naches contains 7.1 acres and was purchased in January 1994; Donald Road, 75.3 acres, purchased in July 1993; Benton City, 16.1 acres, purchased in February 1994; Ferry Road, 117 acres, purchased in January 1993. All sites contain riparian habitats and have Yakima River frontage except the Naches parcel, which is on the Naches River.

Other Protected Areas

The Nature Conservancy owns and protects 106 acres of basalt cliff habitat in the Yakima River canyon as well as 10 acres of bog habitat in the Moxee area to protect the silver-bordered fritillary. The Nature Conservancy and other agencies in the subbasin have made cooperative agreements for the protection and management of habitats in the Union Gap and Teanaway areas. Other conservancies active in the subbasin include the Yakima Greenway Conservancy, Tapteal Greenway, Chamna Natural Preserve and the Cowiche Canyon Conservancy. Tapteal Greenway is a 30-mile green corridor from Benton City to the mouth of the Yakima River. Chamna Natural Preserve contains 2.5 miles of shoreline and 275 acres on the north side of the Yakima River within Richland city limits.

Fish and Wildlife Resources

Fish and Wildlife Status

The Yakima subbasin supports at least 48 species of anadromous, resident native, and exotic fish (Table 1). The species list was produced 8/21/98 by WDFW's ecological interactions team. Original information came from replies to a survey. Only a few species are discussed in detail in the remainder of this document.

Table 9. Species distribution in the Yakima River main stem and associated tributaries

Shaded cells indicate the species is rare (relatively few captures reported) in that stream section

Distance from River Mouth (km)[a]

Species	0-44	45-68	69-161	162-180	181-305
W. brook lamprey			■	■	■
unidentified lamprey			■		■
Pacific lamprey	■	■	■	■	
coho salmon	X	X	X	■	■
spring chinook salmon	X	X	X	X	X
fall chinook salmon	X	X	X	■	
sockeye salmon	■	■	■	■	■
summer steelhead	X	X	X	X	■
bull trout		■		■	■
lake trout			■	■	■
brook trout				■	■
rainbow trout	■	■	X	X	X
cutthroat trout				X	X

Species	0-44	45-68	69-161	162-180	181-305
brown trout					
mountain whitefish	X	X	X	X	X
pygmy whitefish					
Chiselmouth	X	X	X	X	
common carp	X	X	X	X	
Goldfish	X	X			
Peamouth	X	X			
northern squawfish	X	X	X	X	X
longnose dace	X	X	X	X	X
speckled dace	X	X	X	X	X
leopard dace					
Umatilla dace (subspecies)	X	X	X		
unidentified dace	X	X	X	X	X
redside shiner	X	X	X	X	X
bridgelip sucker	X	X	X	X	X
largescale sucker	X	X	X	X	X
mountain sucker					
unidentified sucker	X	X	X	X	X
brown bullhead	X	X			
channel catfish	X	X			
three-spine stickleback					
Pumpkinseed	X	X	X	X	
Bluegill	X	X			
smallmouth bass	X	X	X		
largemouth bass	X	X	X		
black crappie	X	X			
white crappie	X				
yellow perch	X	X			
Walleye					
mottled sculpin			X	X	X
torrent sculpin			X	X	X
piute sculpin			X	X	X
shorthead sculpin					X
prickly sculpin					
unidentified sculpin	X	X	X	X	X
Burbot					
white sturgeon					
Mosquitofish					
Sandroller					

[a]Mouth (Tri-cities) = River km 0; Kiona (Benton City) = rkm 44; Prosser = rkm 68; Yakima = rkm 161;Roza Dam = rkm 180;
Keechelus Dam = rkm 305.

Anadromous Fish

The Yakima Subbasin currently supports natural production of spring and fall chinook, coho and summer steelhead. In MARCH 25, 1995 (64 FR 14517) the National Marine Fisheries Service listed summer steelhead in the mid-Columbia ESU (“Environmentally Significant Unit”), which includes the Yakima Subbasin, as threatened under the Endangered Species Act. Pacific lamprey have become very rare in the Yakima Basin. Pacific Lamprey are a U.S. Fish and Wildlife Service category 2 candidate species. Endemic coho stocks were extirpated about 1980 although naturalized production resulting from releases hatchery smolts have been documented since 1989. Endemic summer chinook were last observed in the early 1970s and are now considered extirpated. Sockeye were historically abundant, but were extirpated following the completion of impassible storage dams below all natural rearing lakes in the late teens and early 1920's.

Spring Chinook

Stocks and Distribution

Historically spring chinook spawned in the upper reaches of the mainstem Yakima and Naches Rivers, most of their larger tributaries and in the three largest lower river tributaries, Satus, Toppenish and Ahtanum Creeks. In terms of major drainage areas, spring chinook spawned in the mainstem Yakima from roughly the Wilson Cr confluence to Lake Keechelus, and probably in the lower reaches of most of the larger tributaries between these points. Among the more important of these upper Yakima tributaries were the Cle Elum River (from mouth to Hyas Lake at RM 34), as well as portions of the Cooper and Waptus Rivers; all of the mainstem Teanaway River and portions of all three of its forks; Taneum and Manastash Creeks below their forks; and a substantial portion of Wenas Cr below its forks. In the Naches drainage, spawning occurred in all of the mainstem Naches above the Tieton River confluence, in portions of the lower Tieton River and especially the North Fork of the Tieton River, in all of the Bumping River below Bumping Lake, in the American River, and in the lower portions of such smaller tributaries as Cowiche Cr and Rattlesnake Cr.

Except for streams rendered inaccessible or unusable by unladdered dams (the upper Cle Elum River and the North Fork Tieton River) or by excessive irrigation diversions or releases (Taneum, Manastash and Wenas Creeks; the lower Tieton River), the current distribution of spring chinook spawning areas is the same as it was historically. The major difference is simply that many fewer fish utilize the remaining areas.

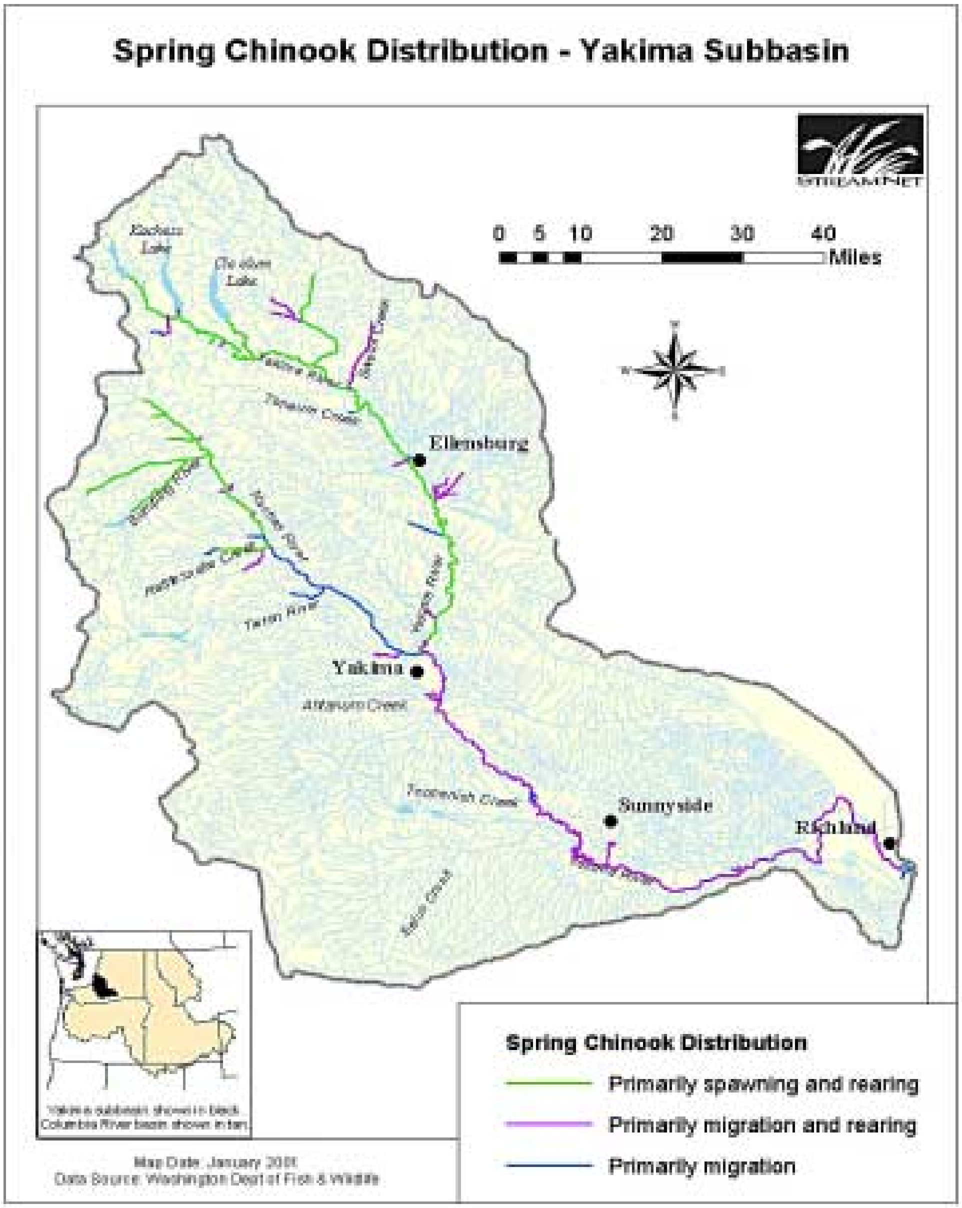
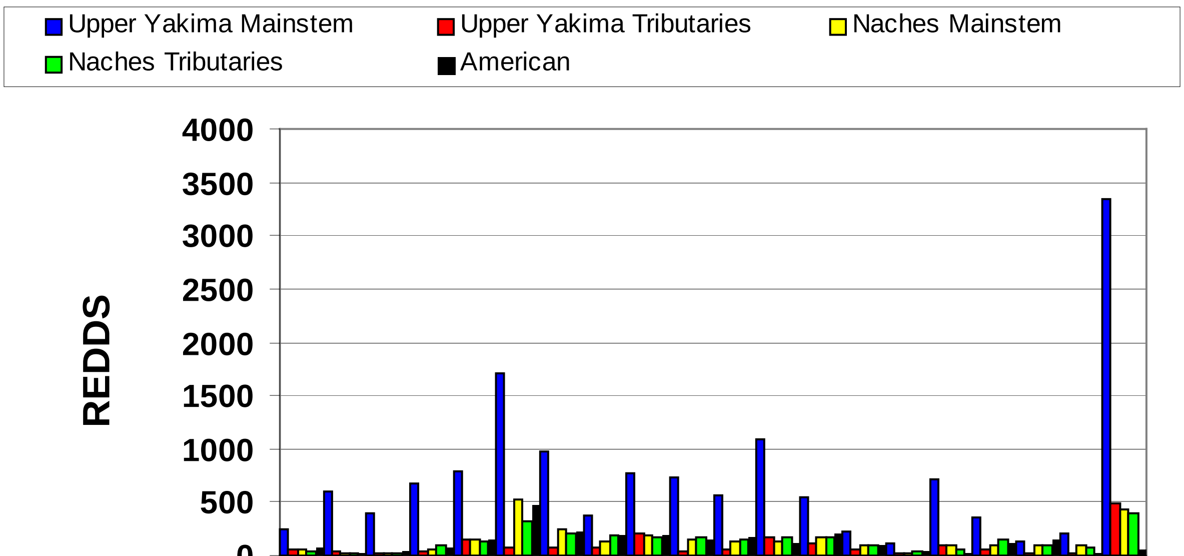


Figure 11. Spring chinook distribution in the Yakima subbasin

The situation is rather different for the three lower tributaries, Ahtanum Creek, Toppenish Creek and Satus Creek. None of these streams support spring chinook runs today. Bryant and Parkhurst (1950) documented the presence of spring chinook in Ahtanum Creek and the lower portions of its forks, as well as lower Satus Creek and its Logy Creek tributary, in the early years of the 20th century. In the absence of any documentation, it is assumed that spring chinook spawn in upper Toppenish Creek in historical times because the habitat there is suitable today, and because similar near-by tributaries (Satus and Ahtanum Creeks) were known to be used.

The genetic composition of the historical spring chinook population is unknown. Currently, three genetically distinct stocks of spring chinook have been identified in the Yakima Basin, the upper Yakima, the Naches, and the American River stocks. The upper

Yakima stock is the most numerous spawning in the Yakima mainstem from Roza Dam (RM 128) to Keechelus Dam (RM 215), as well as the lower Cle Elum River and the North Fork of the Teanaway River. The Naches stock spawns in the Bumping River, the Little Naches River, Rattlesnake Creek and in the mainstem Naches above the Tieton confluence. The third and least numerous stock spawns exclusively in the American River. Fig 12 summarizes the spawning distribution of these three stocks since 1981.



	81	83	84	86	88	89	91	93	94	96	98	99
Upper Yakima Mainstem	237	387.2	674.33	1716	369	766	568	550	226	711	123	199
Upper Yakima Tributaries	57	15	34	77	74	202	62	106	64	103	25	25
Naches Mainstem	64	23	57	526	124	187	139	163	86	99	86	91
Naches Tributaries	36	24	91	323	179	167	151	177	97	57	95	68
American	72	36	72	464	187	187	170	214	89	28	149	27

Figure 12 Yakima spring chinook redd distribution, 1981 through 2000

The degree of hybridization between indigenous Yakima spring chinook and exogenous ("genetically foreign") hatchery stocks cannot be determined. As documented in the Artificial Production section, hatchery-reared juveniles (primarily smolts) have been released into the Yakima Subbasin since at least 1959. The releases made prior to 1999 consisted largely of Carson stock and occurred primarily in the upper Yakima. It is thus reasonable to expect that some introgression between indigenous upper Yakima and Carson fish would have occurred. It should, however, be noted that the hatchery smolts released between 1982 through 1987 were all marked, and that all marked adults that ascended the ladder at Roza Dam into the upper Yakima were captured and sacrificed to retrieve coded wire tags and to prevent hybridization. Nevertheless, existing genetic data is not inconsistent with some commingling of upper Yakima and Carson fish. Busack et al (1991) conducted an electrophoretic genetic stock analysis of Yakima spring chinook. Regarding

Carson-upper Yakima introgression, they state: "Hatchery influence is to be expected in the upper Yakima, and the observed electrophoretic clustering of the Carson and upper Yakima stocks may reflect this, although it is unknown how similar the stocks were before the hatchery operations began."

The first smolt release of the Yakima/Klickitat Fisheries Project (YKFP) occurred in 1999, resulting in the return of (marked) hatchery-origin jacks in 2000. All broodstock for the YKFP program, however, consists exclusively of upper Yakima fish. Therefore risks associated with the introduction of non-native genetic material are not now a concern.

Life History and Demographics

The three stocks of Yakima spring chinook differ in terms of ocean age, mean fecundity, the spawning timing and perhaps sex ratio. They are similar in terms of the timing of spawning runs, smolt outmigration and emergence, as well as in pre-smolt migration patterns and smolt age.

Although all stocks of Yakima spring chinook smolt as yearlings, adult ages do differ among stocks. As shown in Table 10, the upper Yakima stock is overwhelmingly age-4 (71.9 and 90.4% for males and females, respectively) and includes a relatively high proportion of jacks (17% on average). By contrast, the Naches stock is slightly biased in favor of five-year-olds (50.2% males and 59.9% females), and the American stock decidedly so (61.9% males and 74%, females). Both the Naches Basin stocks include about 11% jacks in their spawning runs. Table 2 also indicates a clear difference in sex ratio, with the upper Yakima stock being evenly split between sexes and the two Naches stocks showing a female bias approaching 60/40. The sex ratio figures in Table 11 should be considered provisional because they are based on scale-aged carcasses recovered during spawner surveys. Larger and older fish, and females in general, are disproportionately recovered in spawner surveys and therefore bias the sex-specific age distributions they generate.

Table 10. Sex-specific age distribution of Yakima spring chinook spawners by stock.

Stock and Age		FRACTION OF MALES THAT ARE AGE x	FRACTION OF FEMALES THAT ARE AGE x	FRACTION OF ALL FISH THAT ARE AGE x MALES	FRACTION OF ALL FISH THAT ARE AGE x FEMALES
UPPER YAKIMA	Age III =	17.1%	0.0%	9.1%	0.0%
	Age IV =	71.9%	90.4%	35.4%	45.0%
	Age V =	11.0%	9.6%	5.9%	4.6%
	Age VI =	0.0%	0.0%	0.0%	0.0%
	Sum	**100.0%**	**100.0%**	**50.4%**	**49.6%**
NACHES	Age III =	10.9%	0.0%	7.2%	0.0%
	Age IV =	38.5%	40.0%	24.1%	14.9%
	Age V =	50.2%	59.9%	31.3%	22.3%
	Age VI =	0.4%	0.1%	0.2%	0.1%
	Sum	**100.0%**	**100.0%**	**62.8%**	**37.2%**
AMERICAN RIVER	Age III =	10.9%	0.0%	7.6%	0.0%
	Age IV =	27.0%	24.3%	15.8%	9.1%
	Age V =	61.9%	74.0%	42.6%	23.8%
	Age VI =	0.3%	1.7%	0.2%	0.8%
	Sum	**100.0%**	**100.0%**	**66.2%**	**33.8%**

Table 11. Age-specific mean lengths (mid-eye hypural in cm) for females, Upper Yakima, Naches and American River stocks of spring chinook

Mean lengths estimated from spawning grounds carcasses collected for 1981-2000 broods.

Age	UPPER YAKIMA	NACHES	AMERICAN
Mean Length Age 4	59.7	68.4	64.2
Mean Length Age 5	71.1	68.7	74.7
Mean Length Age 6	--	68.6	78.7
Weighted Mean Length	60.8	68.6	72.2

Table 11 illustrates that Naches and American River females are not only older than upper Yakima females, but considerably larger. Because size and fecundity are positively related, Naches and American River females are also more fecund. On the basis of observed lengths of carcasses and a length-fecundity relationship based on 825 females spawned at the Cle Elum hatchery, it is estimated that the mean fecundity of upper Yakima females over brood years 1981 – 2000 was 4,013 eggs. By the same method, the mean fecundity of Naches females was estimated at 5,067 eggs, and the mean fecundity of American River females at 5,446 eggs.

The duration of the successive freshwater life stages of all three stocks of Yakima spring chinook is summarized in Fig 13.

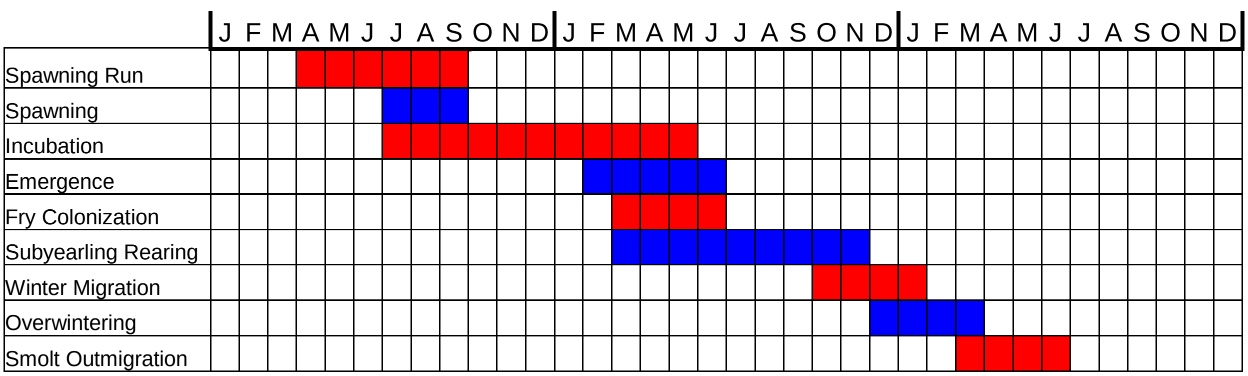


Figure 13. Mean timing of successive freshwater life stages of Yakima Basin spring chinook

Adult run-timing

Radiotagged spring chinook adults were released below Prosser Dam in 1991-92 and monitored through spawning in an effort to determine inter-stock differences in run-timing and delays associated with various dams and fish ladders (Hockersmith et al. 1994). Perhaps the most significant finding of this study was that there was no inter-stock difference in the temporal distribution of fish as they arrived at Prosser Dam. This is true even though there are clear inter-stock differences in the onset and duration of spawning.

Figure 14 shows the cumulative passage of the spring chinook spawning run at Prosser Dam for the years 1983 through 2000. On average, the dates of 10, 50 and 90% cumulative passage are April 10, May 13 and June 3. There is, however, considerable variability from year to year, as the run has been 90% complete as early as May 20 and as late as June 24, a range of 35 days. Although not shown graphically, there is more variability in the timing of the run at Roza Dam, 81 miles upstream. The mean dates of 10, 50 and 90% passage at Roza are May 13, June 3 and July 8, respectively. The run may, however, be 90% complete as early as May 27 and as late as July 22, a range of 56 days.

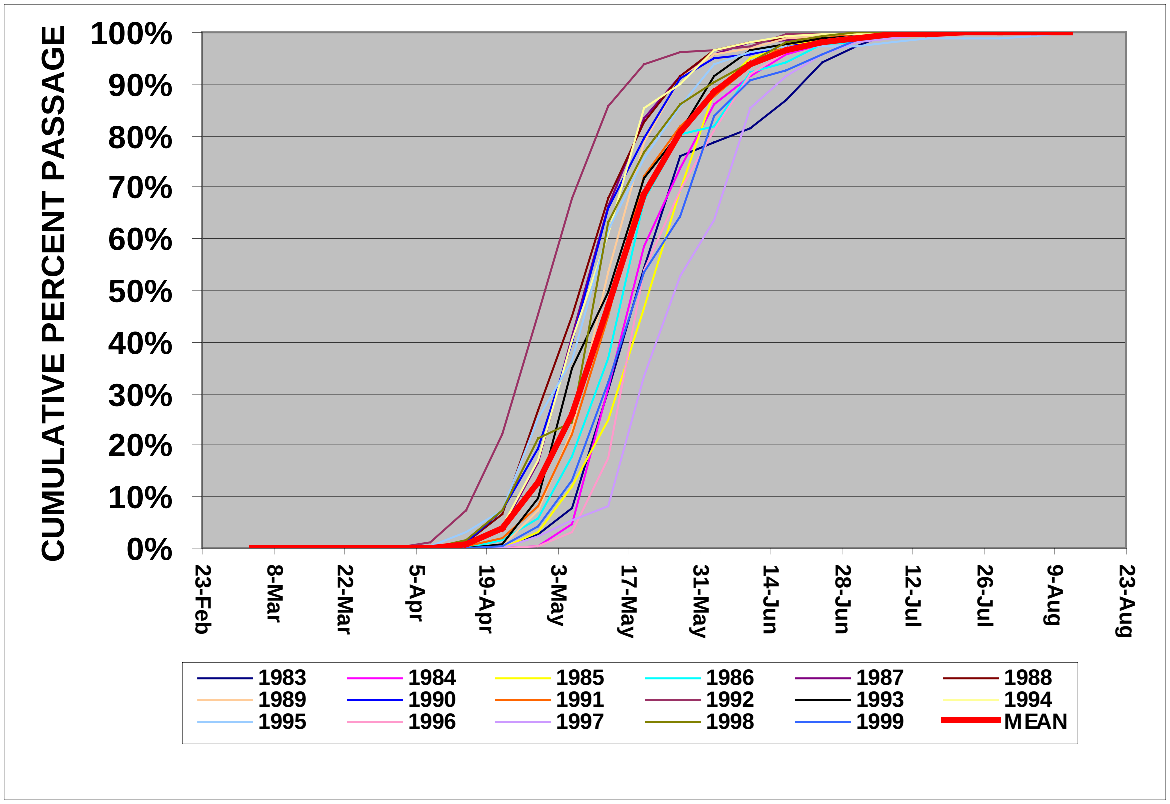


Figure 14. Cumulative passage of Yakima spring chinook spawning run at Prosser Dam, 1983-1999

The main reason for the interannual variability in run timing is the impact of high and low flows on the migration speed of spring chinook spawners (Figure 15). In an average year, the run is half complete 21 days later at Roza than at Prosser. Therefore, given the 81 mile distance between dams, the average fish is traveling at a rate of about 3.8 miles per day. In 1992, a year of unusually low flows, the median fish passed Roza only seven days after it passed Prosser, indicating a migration rate of more than 11 miles per day. Conversely, in years of high flow, like 1997, fish move on average considerably more slowly. This is a pattern observed for the spawning runs of all salmon and steelhead monitored in the Yakima Basin: run-timing is delayed during years of high flow and accelerated in years of low flow.

The onset of spawning activity always is earliest for the American River stock, intermediate for the Naches stock and latest for the upper Yakima stock. Although elevated water temperatures can delay the onset of spawning, American River fish usually begin spawning in late July, Naches fish in late August, and upper Yakima fish in early September. Depending on water temperature, the peak of spawning activity for American River fish ranges from August 8 to August 15, while spawning peaks for Naches and upper Yakima fish range from September 8 to September 18, and from September 15 to October 1, respectively (Fast et al 1991).

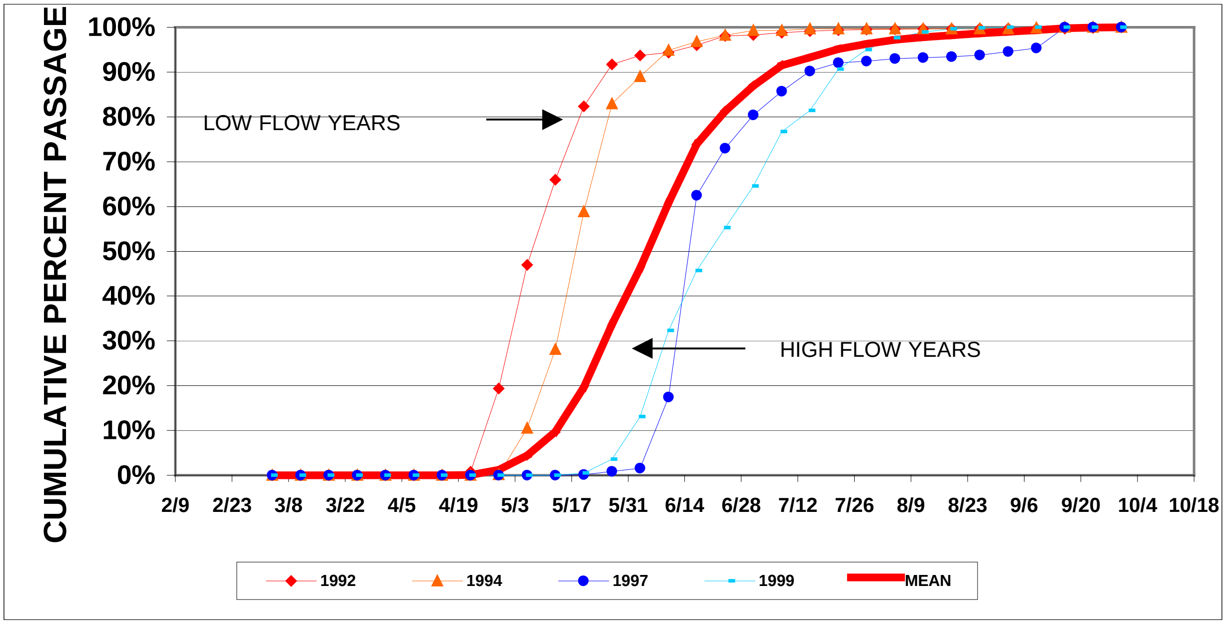


Figure 15. Impact of high and low flows on run-timing of spring chinook spawners at Roza Dam

Emergence appears to be quite closely synchronized across stocks despite five to seven week differences in spawning timing. Fry traps were installed below most redds in the American River and in the upper Yakima River in the late winter of 1984 to estimate emergence timing. In the American River, fry were captured between March 20 and June 4, with a median capture date of April 17. In the upper Yakima, fry were captured between March 8 and June 13, with a median capture date of April 16. This range of emergence timing—from early March through mid June with a peak in mid April—was also seen in the capture dates of fry collected in mesh traps ("redd caps") that were fitted over spring chinook redds in the upper Yakima in 1984, 1985 and 1986. The mean egg-to-fry survival for the redds capped in these years was 60%, a figure assumed representative for upper Yakima spring chinook (Fast et al 1991).

Juveniles from all stocks redistribute themselves downstream the spring and summer after emergence, with highest densities in summer being found well below the major spawning areas, but above Sunnyside Dam. The lack of fish in the lower Yakima mainstem (the mainstem below Sunnyside Dam) is attributed to excessive summertime water temperatures (Fast et al 1991). There is a rather steep thermal gradient that increases from Sunnyside Dam to the Columbia confluence. During the period from mid-July to mid-August, maximum daily water temperatures below Sunnyside (RM 103.8) and Prosser Dams (RM 47.1) have averaged 68 and 78^{o}F, respectively (BOR Hydromet database) over the period of record. Although water temperature has only recently begun to be monitored continuously in the extreme lower Yakima, Yakama Nation data indicate summertime maxima may be about 5^{o}F higher at West Richland (~RM 8) than at Prosser Dam. Water temperatures of 70^{o}F or more are actively avoided by juvenile salmonids, and temperatures in excess of 77^{o}F are lethal.

Another characteristic common to all stocks of spring chinook is an extensive downstream migration of pre-smolts in the late fall and early winter. Various observations over recent years have led to the conclusion that most spring chinook pre-smolts migrate to the lower Yakima mainstem when water temperatures fall sharply in the late fall. This thermal trigger occurs earlier in the upper reaches of the basin. Subyearling migrants begin appearing at the Wapatox Dam smolt trap on the lower Naches (RM 17.1) and at Roza Dam trap on the mid Yakima (RM 127.9) in October and November, and usually during December at the Chandler smolt trap at Prosser Dam on the lower Yakima (Fast et al 1991). Although 10-35% of the juveniles from a given brood year migrates below Prosser Dam during the winter, most fish overwinter in the deep, slackwater portion of the mainstem Yakima between Marion Drain (RM 82.6) and Prosser Dam (Fast et al 1991), and begin their smolt outmigration from the lower river the following spring. Therefore the dominant life history pattern for all wild Yakima spring chinook is this "winter migrant" pattern, which is contrasted with an "upriver smolt" type, which begins outmigration much nearer natal areas in the Naches and upper Yakima drainage.

Figure 16 makes it clear that the outmigration timing of Yakima spring chinook smolts is also quite variable. Although the average dates of 10, 50 and 90% cumulative passage at Chandler are April 6, April 23 and May 20, respectively, the outmigration can be 90% complete as early as April 28 or as late as June 1. The overall timing of the outmigration does not appear to be shifted earlier or later by flow, although the migration rate of actively migrating smolts is positively correlated with flow. The gross timing of the outmigration seems instead to be a function of water temperature the winter preceding smoltification. Specifically, there is an inverse relationship between the mean outmigration date and the thermal units accumulated over the months of December through March: the more degree-days in the Yakima through the coldest part of winter, the earlier the outmigration, and vice versa (Figure 17).

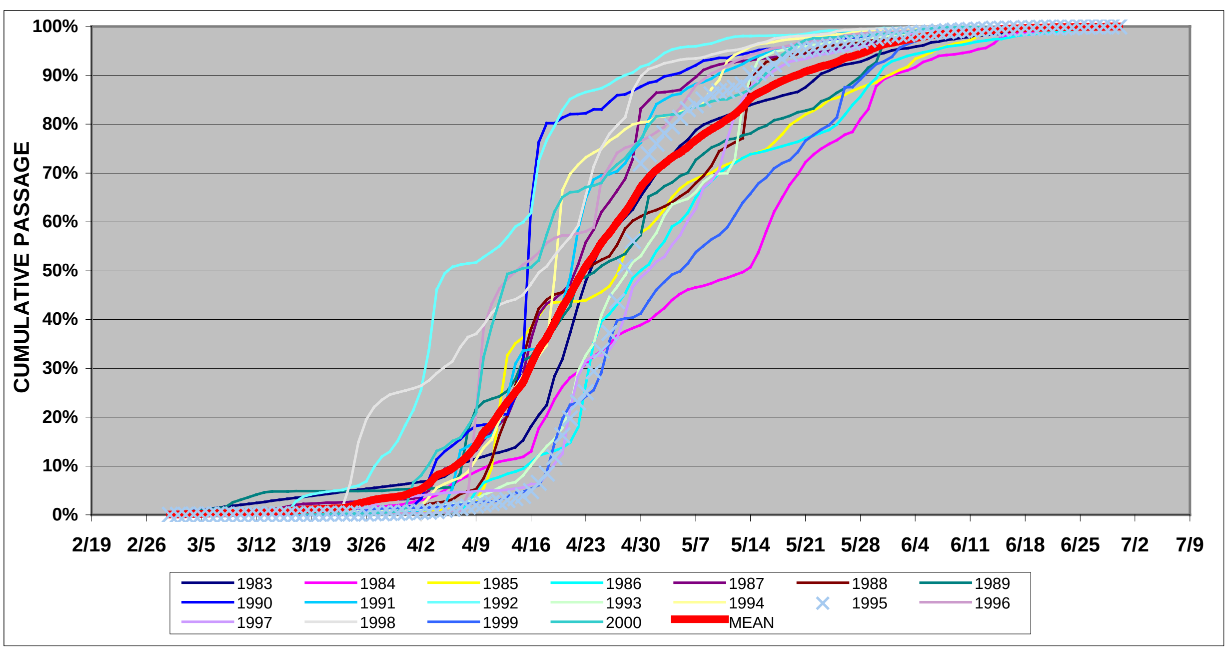


Figure 16. Outmigration timing of spring chinook smolts at Chandler trap, 1983-2000

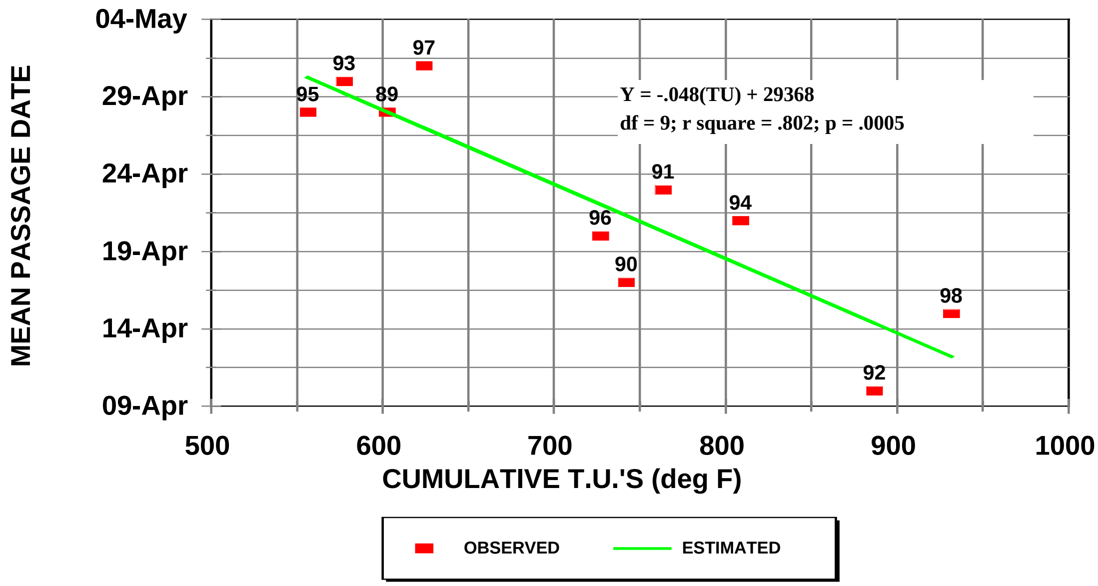


Figure 17. Mean passage date of Yakima Basin spring chinook smolts at Chandler trap

Figures are a function of cumulative thermal units occurring December through March in the Yakima River at Cle Elum the winter preceding. Numbers indicate outmigration year. Similar relationships hold for outmigration timing and winter water temperatures in the Yakima River at Sunnyside and Prosser dams. Spring chinook outmigration dwindles to a few individuals per day by late June, and by convention has been declared finished by the first of July.

Productivity and Trends in Abundance

The abundance and productivity of Yakima Basin spring chinook is a small fraction of historical values. Estimates of the size of historical Yakima spring chinook returns range from ~50,000 (Kreeger and McNeil, 1993) to 200,000 (Anon. 1990). More recently, Yakima Basin spring chinook have been subjected to an Ecosystem Diagnosis and Treatment (EDT) analysis. An integral element of EDT analysis is the estimation of historical equilibrium abundance and productivity.

Table 12. Demographic and performance parameters for current Yakima basin spring chinook populations by geographic stock

Estimated by EDT model, November, 2000

Population	Smolt Productivity (smolts/spawner)	Adult Productivity (returns/spawner)	Smolt Carrying Capacity	Adult Carrying Capacity	Smolt Equilibrium Abundance	Adult Equilibrium Abundance	Life History Diversity (% viable)
American R.	497.6	42.9	80,050	6,636	77,957	6,469	100%
Ahtanum Cr.	57.8	6.0	72,918	7,337	56,667	5,732	100%
Naches R.	440.9	40.8	785,378	68,757	761,030	66,736	100%
Satus Cr.	247.5	31.7	90,324	8,909	84,998	8,499	63%
Teanaway R.	307.2	33.4	232,903	24,534	222,545	23,474	100%
Toppenish Cr.	304.2	31.1	144,499	14,539	127,408	12,842	60%
Upper Yakima	331.6	35.0	1,612,829	160,725	1,555,923	155,365	100%
Basin-wide[a]	**347.0**	**35.5**	**3,041,858**	**294,127**	**2,929,015**	**283,788**	**92%**

a. Basin-wide parameters estimated separately; the sum of individual population values does not equal the basin-wide figure because of rounding .

Table 12 summarizes the results of this analysis, the salient points of which are as follows. First, all potential production areas contributed meaningfully to equilibrium abundance, and basin-wide life history diversity was 92% (*viz.*, 92% of the biologically possible life histories had adult recruitment rates of 1.0 or more and thus were at least marginally viable). Second, basin-wide equilibrium abundance was nearly 284,000 fish and basin-wide productivity was extraordinarily high, with an adult recruitment rate of 35.5 and a smolt productivity rate of 347 smolts per spawner.

By any measure, current production as summarized in Figures 18-19 is a pale reflection of the past. Figure 18 depicts stock-specific escapement for the recent period of record (1982-2000). Over this period basin-wide escapement has averaged 3,591 fish, ranging from 587 in 1995 to 15,959 in 2000. In terms of total returns to the mouth of the Yakima, the mean, maximum and minimum figures are, respectively, 4,285, 19,010 and 666. Thus, assuming historical spring chinook returns ranged from 50,000 to 284,000, current production represents from 1.5 to 8.5% of historical values.

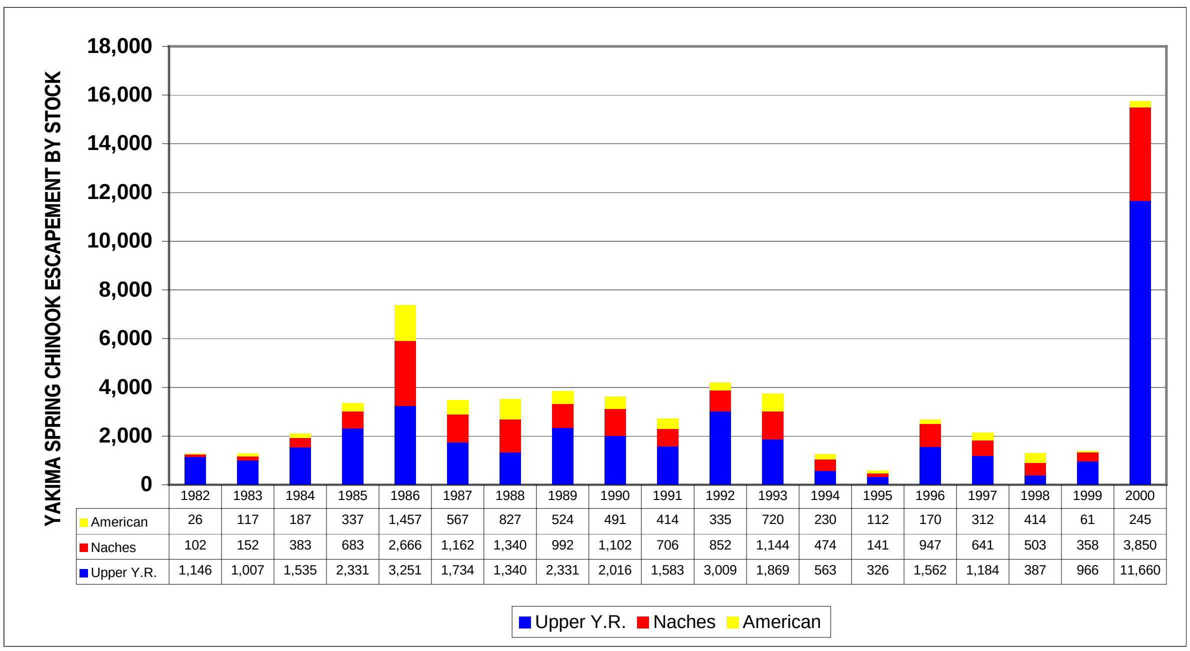
The mean contribution by stock from 1982 – 2000 has been 13% American River fish, 26% Naches stock and 60% upper Yakima stock (YN, unpublished data 2001). These figures, incidentally, compare favorably with those predicted by the EDT model in its simulation of production under current conditions. The EDT model predicts an equilibrium population composed of 8.4 % American River fish, 23.8% Naches fish and 67.7% upper Yakima fish. The EDT estimate of an equilibrium basin-wide escapement of 3,945 fish also matches the mean observation of 3,591 quite well.

Figure 19 shows the escapement of the upper Yakima stock (Roza Dam counts) from 1940 through 2000. A strong cyclical trend in abundance is evident, as is the unprecedented magnitude of the 2000 return. The magnitude of the 2000 return is in fact quite striking in all four of the figures summarizing recent spring chinook production. Over 90% of the fish in the 2000 return are four-year-olds, and therefore represent the 1996 brood year. Clearly it is important to understand the factors that so dramatically increased the productivity of the 1996 brood.

At the present time, the best explanation is that environmental conditions for the '96 brood improved substantially along every point of the life cycle. The '96 brood spawned after the flood of February, 1996, an event which scoured and cleaned streambeds. Fry then emerged into a "refurbished" environment, one which had become substantially more complex as a result of the river having carved many new side channels and acquired thousands of new pieces of large woody debris. Instream flows throughout the Yakima Basin were unusually high, and water temperatures unusually cool as parr reared in the summer of 1997. Instream flow was also good in both the Yakima and the Columbia during the outmigration of 1998. Finally, there is both direct and indirect evidence that ocean conditions improved substantially in 1998. Indirect evidence of improved ocean conditions is evident both in the large increase in the Bonneville jack count in 1999 and the Bonneville count of upriver spring chinook adults in 2000. Direct evidence is provided by. Significantly, a large return of Naches and American River fish is expected for 2001, as the majority of these stocks are five-year-olds (age-5 fish in 2001 are '96 brood). Moreover, the jack count at both Prosser Dam and Bonneville Dam was high in 2000. Indeed, based on regressions of jack counts and returns of age-4 fish and cohort ratios, the YN has predicted a total return of 27,907 Yakima spring chinook in 2001: 20,055 upper Yakima fish (9,564 wild and 10,991 hatchery), and 7,352 Naches and American River fish.

Figure 20 shows that hatchery fish have contributed relatively little to the return since 1982. During the period 1984 – 1990, when experimental fish released during Yakima River Spring Chinook Enhancement Study were returning, hatchery fish contributed only 9.3% to the return, with a range of 1.1 to 34.1%. Returns for 2000 include 791 hatchery-reared jacks, 4% of the total. These fish are the first returns of the YKFP, and were released as smolts in 1999.

Figure 21 shows how basin-wide returns were utilized – *viz.*, the relative magnitude of the numbers of fish that were harvested, utilized for broodstock or other scientific endeavors, or allowed to escape. From 1982 though 2000, the harvest rate ranged from 1.1 to 23.6% and averaged 12.1%. Except for 100 fish taken in a sport fishery in 2000 (the first sport fishery in 40 years), all harvest occurred in the tribal ceremonial and subsistence fishery, which is managed for an exploitation of 20% or less. Collection of adults for broodstock or other scientific purposes has also been quite low, except for 1998, when 48.7% of the upper Yakima return (51.3% of the count of fish at Roza Dam) were taken for broodstock by the YKFP. Note that YKFP policy is to take no more than 50% of the upper Yakima escapement for broodstock. Considering all sources of utilization, natural escapement has ranged from 98.1 to 51.8% of the total return, with a mean of 83.7% of the total return.



	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
American	26	117	187	337	1,457	567	827	524	491	414	335	720	230	112	170	312	414	61	245
Naches	102	152	383	683	2,666	1,162	1,340	992	1,102	706	852	1,144	474	141	947	641	503	358	3,850
Upper Y.R.	1,146	1,007	1,535	2,331	3,251	1,734	1,340	2,331	2,016	1,583	3,009	1,869	563	326	1,562	1,184	387	966	11,660

Figure 18. Stock-specific escapement of Yakima spring chinook, 1982-2000

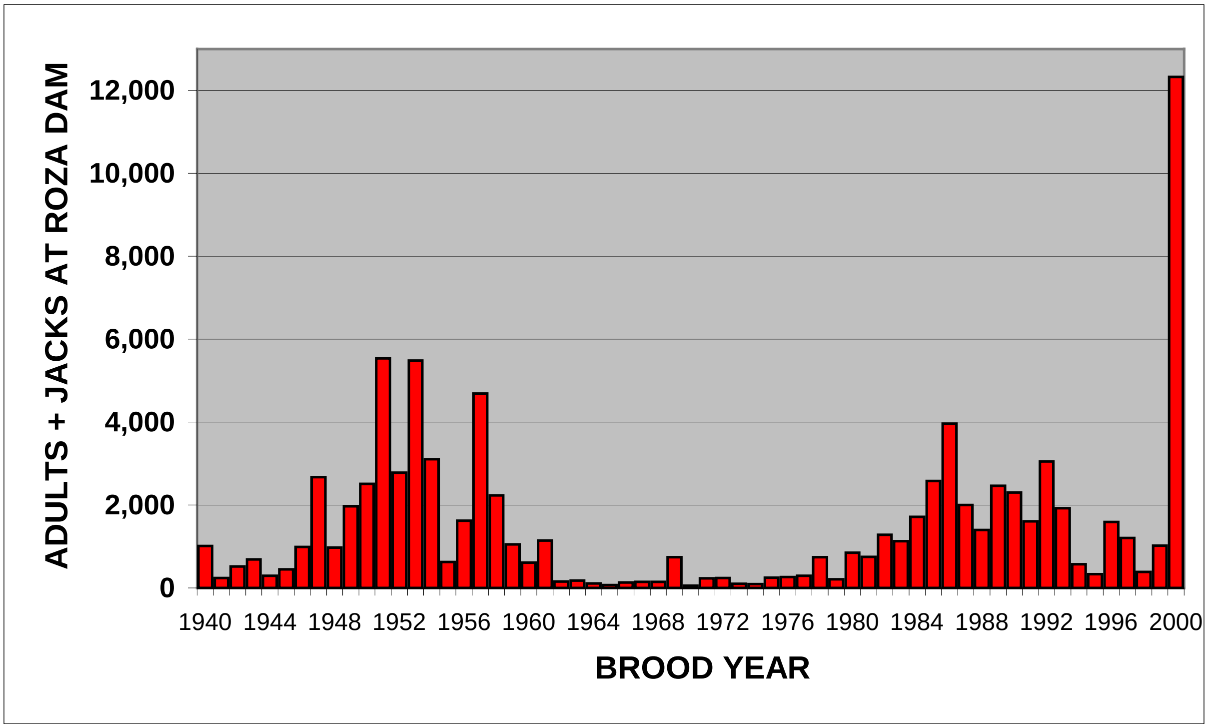
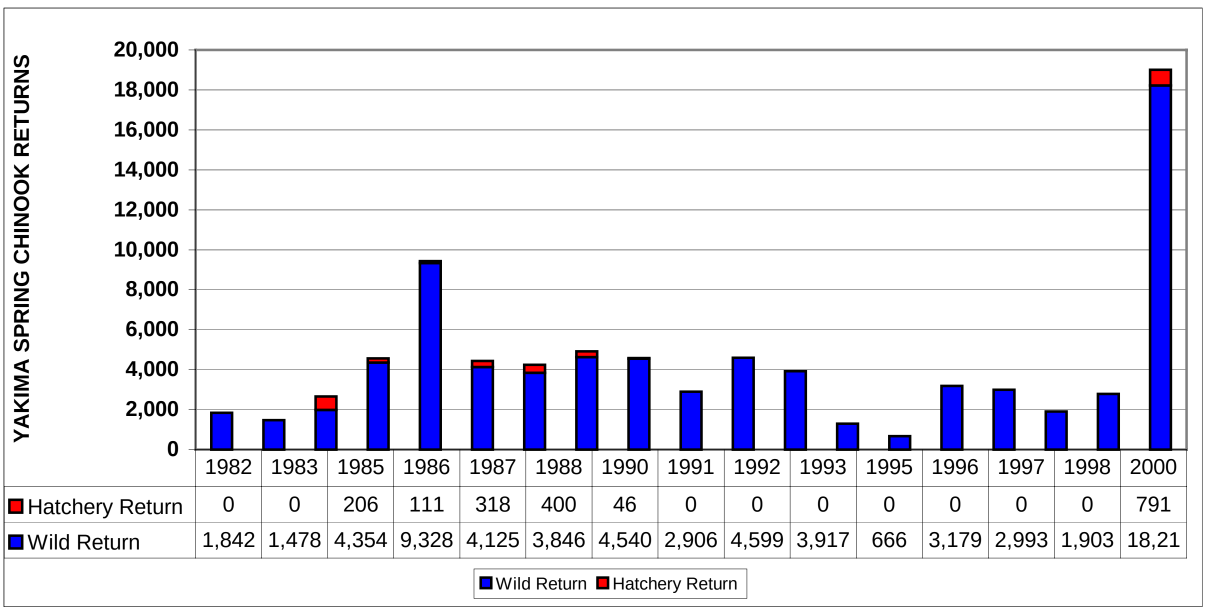
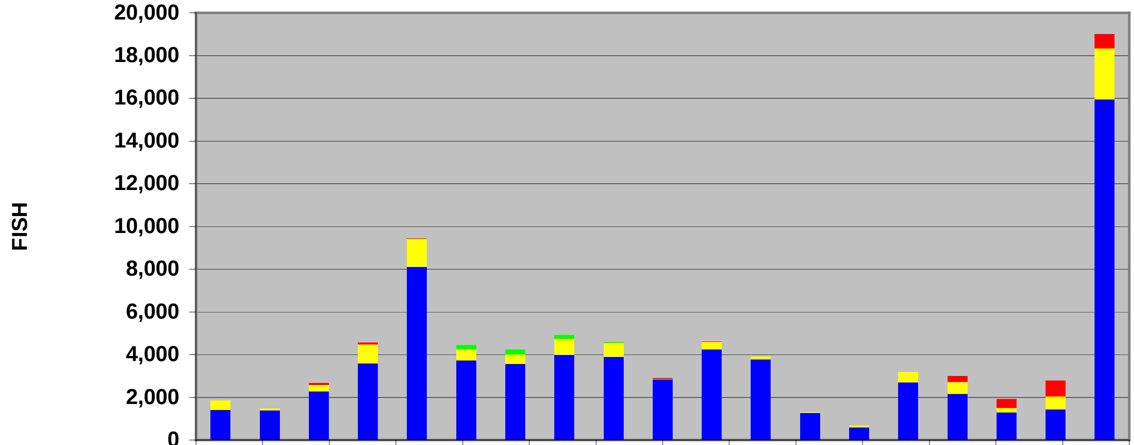


Figure 19. Escapement of upper Yakima spring chinook, 1940-2000



	1982	1983	1985	1986	1987	1988	1990	1991	1992	1993	1995	1996	1997	1998	2000
Hatchery Return	0	0	206	111	318	400	46	0	0	0	0	0	0	0	791
Wild Return	1,842	1,478	4,354	9,328	4,125	3,846	4,540	2,906	4,599	3,917	666	3,179	2,993	1,903	18,21

Figure 20. Hatchery and wild returns of Yakima spring chinook, 1982 – 2000



	1982	1983	1985	1986	1987	1989	1990	1992	1993	1994	1996	1997	1998	2000
Removed					194	184	31							
Broodstock			97	16				18				261	408	667
Harvest	434	84	865	1,340	517	747	663	345	129	25	475	575	188	2,384
Escapement	1,408	1,394	3,598	8,083	3,732	3,983	3,891	4,236	3,788	1,277	2,704	2,157	1,307	15,95

Figure 21. Annual escapement, harvest, broodstock collection and other removals of returning Yakima spring chinook. 1982 – 2000

Table 13 summarizes annual smolt production and productivity for Yakima spring chinook. In this table, overall productivity is adult recruitment rate (adult progeny per spawner), which is the product of the in-basin (smolts/spawner) and out-of-basin (smolt-to-adult survival) productivity components. Over the period of record, adult productivity has ranged from 0.2 to 8.7 adult progeny/spawner, with a mean of 2.2, while smolt productivity has ranged from 19 to 256 smolts/spawner with a mean of 87. The Yakima Basin and the region as a whole experienced drought or near-drought conditions over the years 1986 through 1993, and these years of poor conditions are reflected by adult recruitment rates that are less than 1.0 for seven of the eight years.

Current overall productivity is 6.2% of the historical rate estimated by EDT (35.5 adult progeny/spawner), and current in-basin productivity is about 25% of the estimated historical rate (347 smolts/spawner). These figures imply that current out-of-basin productivity (smolt-to-adult survival) is also 25% of the historical value, because 0.25^2 is about 6.2%.

Table 13. Annual basin-wide smolt and adult productivity of Yakima Basin spring chinook

BROOD YEAR	SMOLT YEAR	SMOLTS[a]	SMOLTS PER SPAWNER	SMOLT TO ADULT SURVIVAL[b]	ADULT RECRUITMENT RATE[b]
1981	1983	245,921	201	2.5%	5.1
1982	1984	365,755	256	2.1%	5.4
1983	1985	140,755	104	3.3%	3.4
1984	1986	218,321	96	1.7%	1.6
1985	1987	252,165	70	1.8%	1.2
1986	1988	260,932	33	1.7%	0.6
1987	1989	72,460	19	3.3%	0.6
1988	1990	134,162	44	4.2%	1.8
1989	1991	104,405	26	2.6%	0.7
1990	1992	123,041	34	1.0%	0.3
1991	1993	87,844	31	0.6%	0.2
1992	1994	162,989	38	2.2%	0.8
1993	1995	168,471	44	2.0%	0.9
1994	1996	207,365	181	0.8%	1.4
1995	1997	49,524	84	3.4%	2.9
1996	1998	278,706	103	8.4%	8.7
1997	1999	291,982	135		
1998	2000	84,821	71		

a. Estimated as the sum of "spring smolts", counted from March 1 through the end of the outmigration, and one half of the "winter migrants" – subyearlings passing Prosser the winter preceding the spring of outmigration.

b. Figures for brood year '96 estimated: the historical proportion of age-5 to age-4 returns was assumed.

One final point about the figures in Table 13. As is evident in Figure 22, there is a significant positive correlation between in-basin and total productivity, but no relationship between in-basin and out-of-basin productivity. This may mean that the factors which control smolt production inside the basin and smolt survival outside the basin are not correlated, and that differences in adult recruitment between years have usually been attributable to differences in smolt productivity. Whatever the explanation the data points for the 1996 brood are clearly outliers and may reflect a change of state for the production system.

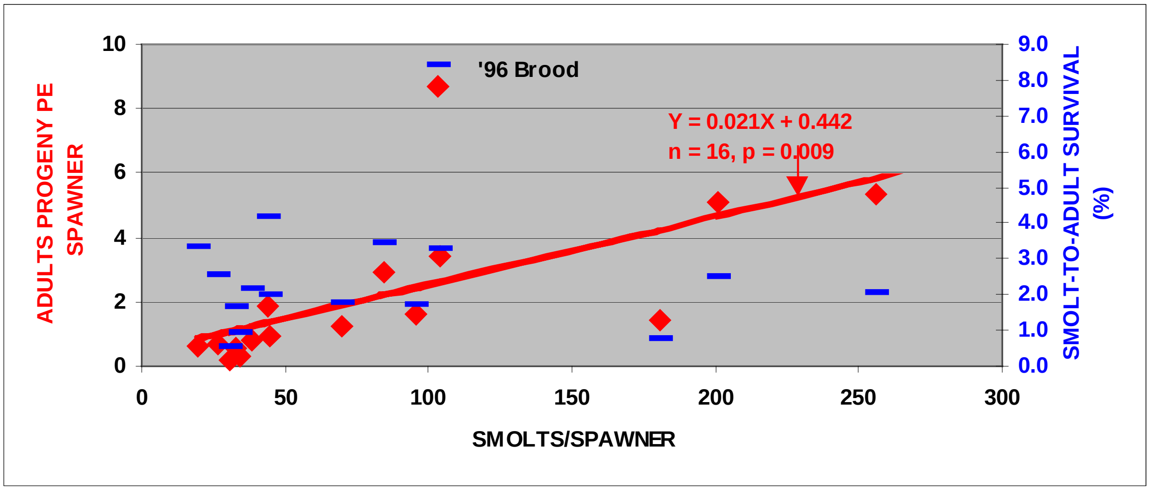


Figure 22. Adult recruitment rate and smolt-to-adult survival as a function of smolt productivity (smolts/spawner) for Yakima Basin spring chinook, 1981 – 1996 brood years.

Fall Chinook

Stocks and Distribution

Little is known about the historical distribution of fall chinook although managers generally believe the primary production area was the same as it is today: the lower ~100 miles of the Yakima mainstem, from the current site of Sunnyside Dam to the Columbia confluence (Figure 23). A *Yakima Herald* article from October of 1944 reported a "volunteer run" of fall chinook over Roza Dam and into the Naches River as far as Wapatox Dam. Similarly, Roza Dam counts from 1941 through the 1950's record a handful of chinook in September and October (WDF Annual Report 1964), some of which were probably fall chinook. Although the historical distribution of fall chinook may have been somewhat broader than now, there is, with one exception, no reason to suspect the general area of production was located differently. There is, however, reason to suspect that the upper portions of their range were utilized relatively more successfully historically. This is because the temperatures in the lower portion of the drainage have increased to the point that fish spawned toward the upstream limit of the range are unlikely to reach smolt status and migrate out of the basin before temperatures become prohibitively high downstream.

The exception is the self-sustaining population of fall chinook that now occurs in Marion Drain. Marion Drain is a 19-mile-long drainage ditch for the Wapato Irrigation Project (WIP) which was dug early in the 20th century to drain wetlands and enlarged over the years to serve as a major delivery canal for WIP. It discharges into the Yakima River at RM 82.6, 2.2 miles upstream of the mouth of Toppenish Creek.

The scant literature on the subject suggests that historical abundance probably ranged from about 38,000 to 100,000. These figures are based on two documents: Kreeger and McNeil, 1993 and the Yakima Subbasin Plan (YIN et. al 1990). Kreeger and McNeil (1993) argue that 3.8% of the historical run of salmon and steelhead in the entire Columbia Basin should have been produced by the Yakima because it represented 3.8% of the historical Columbia Basin watershed. On the basis of a moving average of peak historical Columbia River catch data and assumed exploitation rates, they estimate that the historical run of summer chinook, and of spring and fall chinook combined, was on the order of 2.7 million and 2.0 million fish, respectively. If 3.8% of all spring and fall chinook entered the Yakima, the historical run to the Yakima would have been 76,400. It is often assumed that the historical summer chinook run was twice as large as either the spring or the fall chinook runs, which were approximately equal in size. If this held for the Yakima, the historical run of fall chinook would be about 38,000 fish. The Yakima Subbasin Plan bases its considerably higher estimate on the amount of suitable spawning habitat for chinook historically present in the Yakima Basin, and the area taken up by a typical chinook redd. This approach yields estimates of ~200,000 for spring chinook and ~200,000 for summer and fall chinook combined. If summer and fall chinook, whose spawning distributions overlapped broadly, are assumed equally abundant, the historical abundance of fall chinook would have been on the order of 100,000.

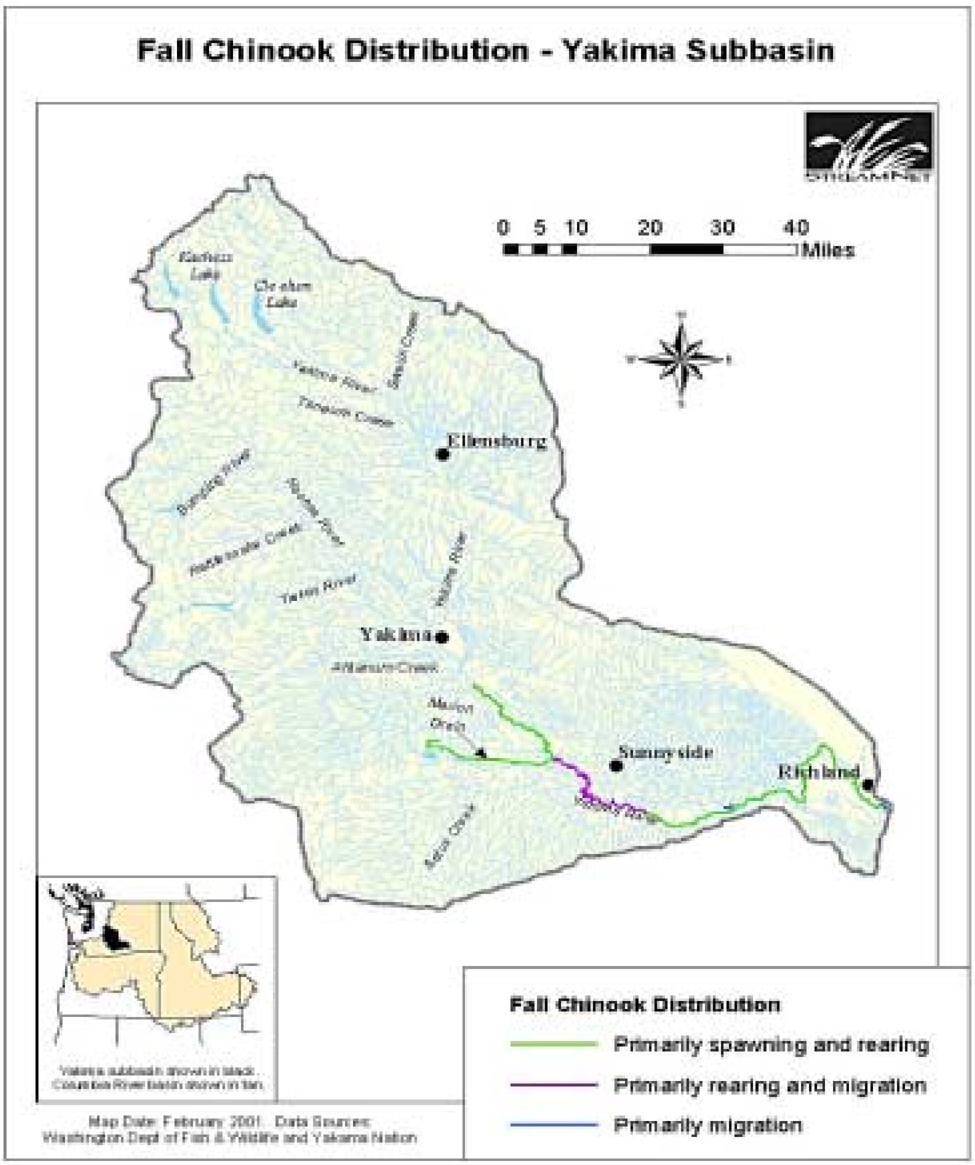


Figure 23. Fall chinook distribution in the Yakima subbasin

The recent abundance of fall chinook is summarized in Figure 23. As with all other Yakima basin stock, fall chinook production today is only a small fraction of historical estimates. Escapement above Prosser Dam has ranged from 232 in 1988 to 1,612 in 1992. However, because about 70% of the spawning occurs below Prosser Dam[1], the true range and mean might be more on the order of 773 to 5373,with a mean of 3,159, from 3 to 8% of historical estimates. Figure 24 also shows the Marion Drain redd count over the same period of record. Marion drain escapement does not track above-Prosser escapement particularly well. Neither of the above-Prosser population displays a clear trend over these18 years, except that Marion Drain escapement fell sharply after 1988 and has yet to recover.

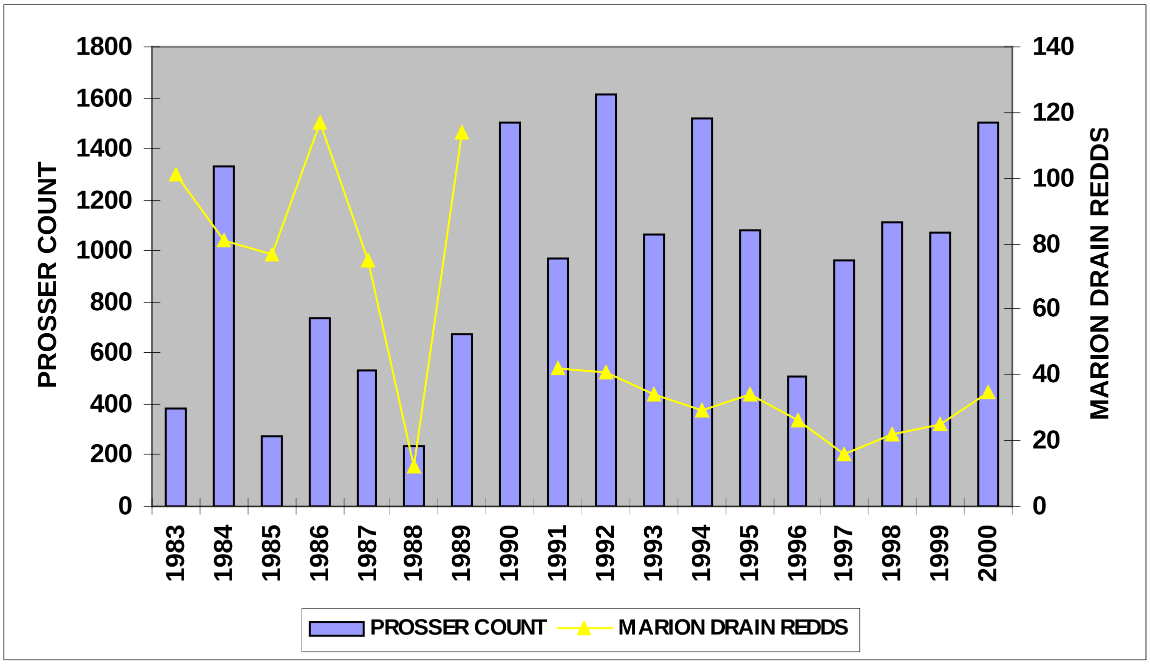


Figure 24. Prosser Dam counts of all chinook (adults + jacks) and Marion Drain

[1] Because turbidity usually precludes accurate redd counts, the proportion of fall chinook spawning below Prosser has had to be based on two resonably successful aerial redd counts in which the number of redds and live fish above Prosser Dam was only 30% of the total..

Table 14. Summary statistics, hatchery fall chinook smolt releases in the Yakima subbasin 1983 - 2000

Year	Hatchery Plants Above Prosser		Hatchery Plants Below Prosser		Hat. Smolt Survival To Prosser, Pen Reared Fish Only (%)	Hat. Smolt Survival To Prosser, Direct Releases Only (%)	Catch Rate In Oceanic And Columbia River Fisheries (% Of No. Tagged Fish Released)
	No.	% Clipped	No.	% Clipped			
1983	0	N.A.	323,796	0	N.A.	N.A.	NO DATA
1984	105,097 (Sunnyside Dam)	100 (98.8% tagged)	479,556 (84.6% Horn, 15.4% Prosser)	21.5 (all Horn; 99,522 tagged)	N.A.	27.1	.09%
1985	100,655 (Sunnyside Dam)	100 (100% tagged)	1,763,500 (52.4% Horn, 47.6% Prosser)	6.1 (all Prosser, all tagged)	N.A.	15.7	PROSS = .09% SUNNY = 0.0%
1986	97,460 (Sunnyside Dam)	100 (96.1% tagged)	1,547,700 (53.2% Horn, 46.8% Prosser)	6.5 (all Prosser, all tagged)	N.A.	32.2	PROSS = .03% SUNNY = 0.0%
1987	196,980 (Sunnyside Dam)	100 (100% tagged)	872,609 (all Prosser)	22.6 (all Prosser, all tagged)	N.A.	44.4	PROSS = .15% SUNNY = .09%
1988	444,795 (55.3% Wapato net pens, 44.7% Sunnyside Dam)	100 (100% tagged)	1,375,888 (all Prosser)	14.5 (all Prosser, 95.6% tagged)	22.6	6.7	PENS = .001% PROSS = .005% SUNNY = 0.0%
1989	540,198 (63% Wapato net pens, 37% Sunnyside Dam)	90.6 (85% Wapato fish clipped and tagged; 100% Sunnyside fish clipped and tagged)	1,430,316 (24% Horn, 76% Prosser)	14.0 (18.4% Prosser fish clipped and tagged; 0% Horn fish clipped and tagged)	18.5	8.7	PENS = .001% SUNNY & WAPATO = .0005%
1990	679,714 (70.6% Wapato net pens, 29.4% Sunnyside Dam)	45.6 (39.9% Sunnyside fish clipped and tagged; 50% Wapato fish clipped, 48% Wapato fish clipped and tagged)	880,344 (all Prosser)	9.2 (9.2% Prosser fish clipped and tagged)	38.0	33.9	PENS = .05% PROSS & SUNNY = .05%
1991	478,916 (Wapato net pens); 1,152,829 (Roza WW#3)	100% Wapato fish clipped and tagged; all of the Roza WW#3 fish were ventral clipped, but none were tagged.	0	N/A	35.0	31.4	PENS = .04%
1992	0	N/A	0	N/A	N/A	N/A	No Data
1993	165,428 Frontage Rd.	98.5% tagged, 100% clipped	582,731 Prosser ?	98.5% tagged, 100% clipped	N/A	5.5	.005%
1994	0	N/A	1,703,892 Prosser Hatch.	11.6%	N/A	N/A	.001%
1995	0	N/A	1,694,188 Prosser Hatch.	11.7%	N/A	N/A	NO DATA
1996	0	N/A	1,885,504 Prosser Hatch.	10.6%	N/A	N/A	NO DATA
1997			1,693,000				
1998			1,965,000				
1999			1,700,000				
2000			1,295,037				

WDFW estimated fall chinook escapement below Prosser Dam in 1998, 1999 and 2000. WDFW estimated that 1998 below Prosser Dam fall Chinook run size ranged from 667 based on carcass tagging and recovery data to 1,203 fish based on expansion of redd counts. The redd count was 188. (Watson and LaRiviere 1999). An insufficient number of recaptured carcasses precluded the use of the carcass tagging and recovery method to estimate the number of fall chinook spawning in the lower Yakima River in 1999. By applying an area under the curve model, using redd counts, WDFW estimated 2069 fall chinook spawned below Prosser Dam in 1999. The redd count was 463 (Watson and Cummins 2000). In 2000 the lower Yakima River escapement estimate from Prosser Dam down stream using the area under the curve method from redd counts was 3,125. The 2000 redd count was 689 (Rick Watson, personal communication, 1/30/2001).The redd count method, at best provides a rough estimate of run size because visibility of redds is dependent on water visibility. Visibility generally ranged from .3 to 1.7 meters during these surveys. Therefore, all redds were not counted.

The genetic status of the historical fall chinook population is unknown, but two genetically distinct stocks of fall chinook currently occur in the Yakima River, the lower mainstem (or "mainstem") stock, and the Marion Drain stock (Busack and Marshall 1991, Marshall et al. 1995, Talbot 1999). Although in terms of run-timing and spawning timing, both stocks are "Upriver Brights" (URB's), electrophoretic and demographic differences led Marshall et al. 1995 to assign the two populations to different genetic diversity units (GDUs): the Marion Drain population is assigned to the mid-Columbia and Snake fall chinook GDU (GDU 6), whereas the mainstem population is assigned to the upper Columbia fall chinook GDU (GDU 5). The mainstem stock spawns in the lower Yakima River primarily below Wapato Dam (RM 106.7), and most intensively between the Benton City Bridge (RM 29.8) and Horn Rapids Dam (RM 18). The Marion Drain stock spawns primarily in Marion Drain, although some fish probably spawn in the mainstem near the mouth of the drain.

Based on existing electrophoretic and life history data, the genetic variability within the Marion Drain population represents a substantial portion of the genetic variability found in mid-Columbia summer and fall chinook. What this variability means to the future productivity of chinook stocks in the area is unclear. Possibly it means nothing, and the variability is nothing more than a curiosity. But it may be quite valuable, and the Marion Drain population may prove to be an important part of the effort to rebuild fall chinook in the Yakima Basin.

Demographics and Life History

Little is known of the demographic characteristics or life history strategies of historical fall chinook populations. Given the very large loss of habitat diversity, it is reasonable to assume that historical life history diversity was greater than it is today. One important life history difference between present-day and historical fall chinook populations is known: smolt outmigration timing. In intact habitats, many populations of ocean-type[2] chinook begin their smolt outmigration in May, reach a peak in June or July, and continue migrating through September (Groot and Margolis, 1991). Just such an outmigration of subyearling chinook was observed in the Yakima in 1928, 1929 and 1930 (Lichatowich,

[2] "Ocean type" chinook migrate to the ocean in their first year of life as "subyearlings."

1992). This timing contrasts sharply with the current outmigration, which typically ends in early July (Figures 25 and 26).

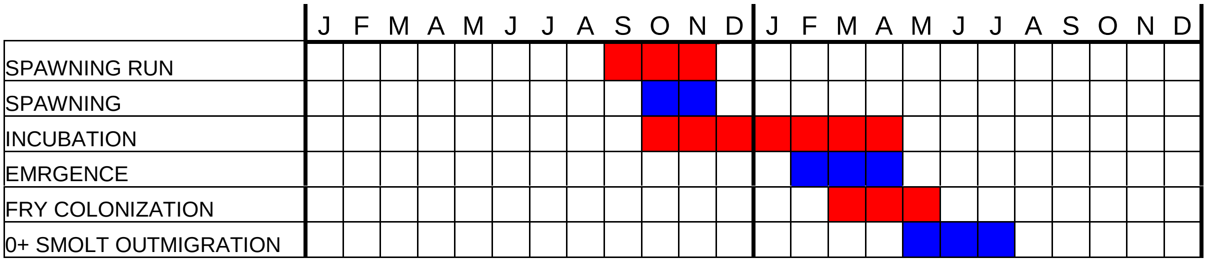


Figure 25. Mean timing of successive freshwater life stages of Yakima Basin fall chinook

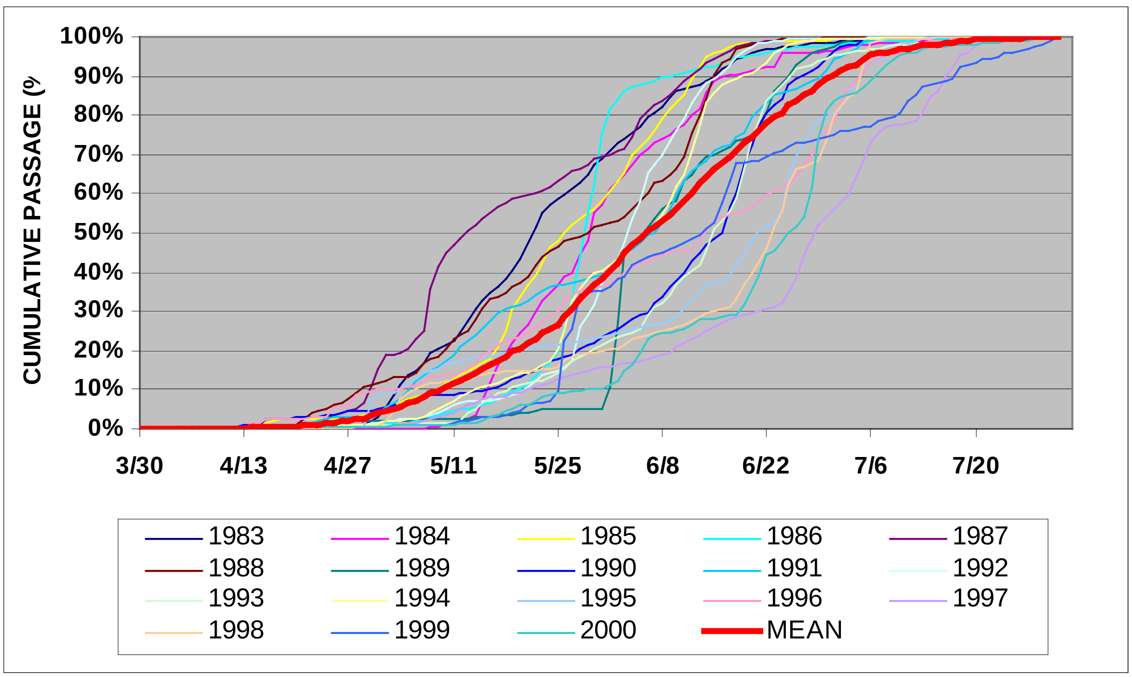


Figure 26. Passage timing of wild Yakima River fall chinook smolts at Chandler trap, 1983 – 2000

Figure 26 summarizes the outmigration timing for wild, subyearling, fall chinook smolts at Chandler since 1983[3]. The average dates of 10%, 50% and 90% passage are May 9, June 6 and July 1, but there is a very large amount of interannual variability. It is possible that much of this variability is due to temperature – to a temporary "stalling" of the outmigration by a short period of high temperatures, or to a premature truncation of the entire run by a prolonged period of high temperatures which directly or indirectly kills the later portion of the outmigration. This hypothesis is supported by two observations. One is the strong inverse relationship between the date of 90% passage and mean Chandler water temperature from June 15 – July 15 (Figure 27). This data shows that the outmigration ends

[3] All fall chinook smolts in the Yakima are subyearlings, but not all subyearling smolts are fall chinook. About 40% of a sample of small chinook smolts collected at Chandler in july were subsequently found by electrophoretic techniques to be spring chinook (Busack et al 1991). A subyearling-smolt life history may once have contributed significantly to the productivity of Yakima spring chinook, but they definitely do not now. Of the thousands of adult spring chinook scales aged over the past 20 years, perhaps one or two indicated ocean entry as a subyearling.

considerably earlier during hot years, and that an increase of ten degrees F in late spring water temperatures usually means the outmigration will end nearly a month earlier.

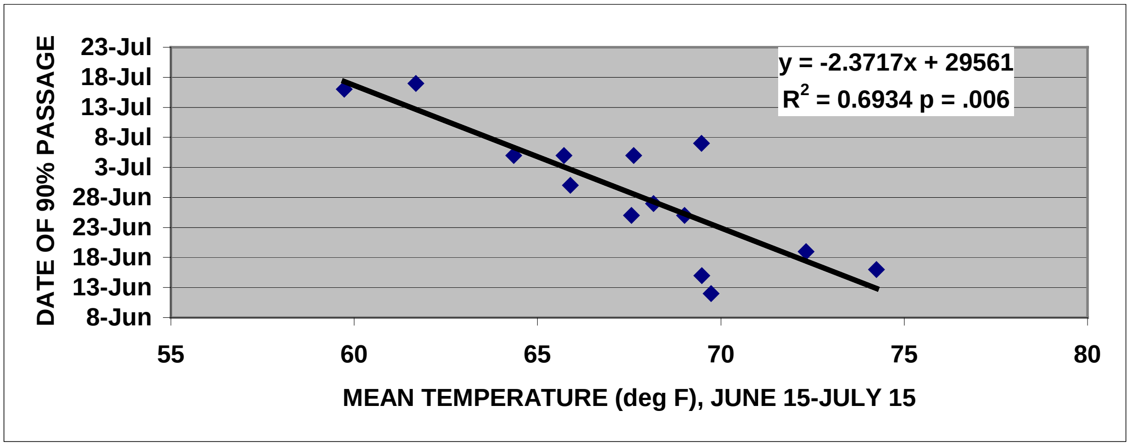


Figure 27. Inverse relationship between date of 90% passage of Yakima fall chinook smolts at Chandler and mean water temperature at Chandler over the period June 15 – July 15, outmigrations of 1988 – 2000

WDFW collected fall chinook carcasses (Richland to Prosser Dam) to determine age distribution and sex ratios in 1998, 1999, and 2000 (Tables 15, 16, 17). Lower Yakima fall chinook age data from wild and supplementation fish for 1998, based on 172 carcasses with readable scale samples was 3.5% age 2, 52.9% age 3, 28.5% age 4, 15.1% age 5. Wild fall chinook age distribution was 6.5% age 2, 27.4% age 3, 37.0% age 4, and 29.1% age 5. The hatchery supplementation age distribution was 2.2% age 2, 62.7% age 3, 26.9% age 4, and 8.2% age 5. Percent hatchery/wild contribution was 73/27 and male female ratio was 61/39 (Watson and LaRiviere 1999). Based on scale analysis of 277 wild and supplementation fish, the lower Yakima River age composition was 0% age 2, 22.5% age 3, 66.2% age 4, 11.3% age 5 in 1999. Wild fall chinook age distribution was 0% age 2, 24.1% age 3, 68.5% age 4, and 7.4% age 5. The hatchery supplementation age distribution was 0% age 2, 22.2% age 3, 65.6% age 4, and 12.2% age 5. Percent hatchery/wild contribution was 81/19 and male female ratio was 46/54 (Watson and Cummins 2000). Age and sex analysis for lower Yakima fall chinook in 2000 is summarized in Table 17. Based on scale analysis of 564 wild and supplementation fish, the lower Yakima River age composition was 6.2% age 2, 10.5% age 3, 43.1% age 4, 40.2% age 5 in 2000. Wild fall chinook age distribution was 15.6% age 2, 18.8% age 3, 31.2% age 4, and 34.4% age 5. The hatchery supplementation age distribution was 1.6% age 2, 6.3% age 3, 48.9% age 4, and 43.1% age 5. Percent hatchery/wild contribution was 67/33 and male female ratio was 48/52 (Watson, Hoffarth, and Cummins, 2001).

Table 15. 1998 Lower Yakima river fall chinook carcass recoveries by age and sex

Actual Age	2	3	4	5	Unreadable	**Totals**
Male	6*	66	20	12	9	**113**
Female	-	25	29	14	3	**71**
Totals	6	91	49	26	12	**184**

Note*: One chinook age 2 was classified as an adult by field staff, that used criteria of > 56 cm.

Table 16. 1999 Lower Yakima River fall chinook carcass recoveries by age and sex

Actual Age	2	3	4	5	6	Totals
Male	0	38	81	12	0	131
Female	0	26	107	20	0	153
Totals	0	64	188	32	0	284

Table 17. 2000 Lower Yakima River fall chinook carcass recoveries by age and sex

Actual Age	2	3	4	5	6	Totals
Male	35	52	89	96	0	272
Female	0	7	154	131	0	292
Totals	35	59	243	227	0	564

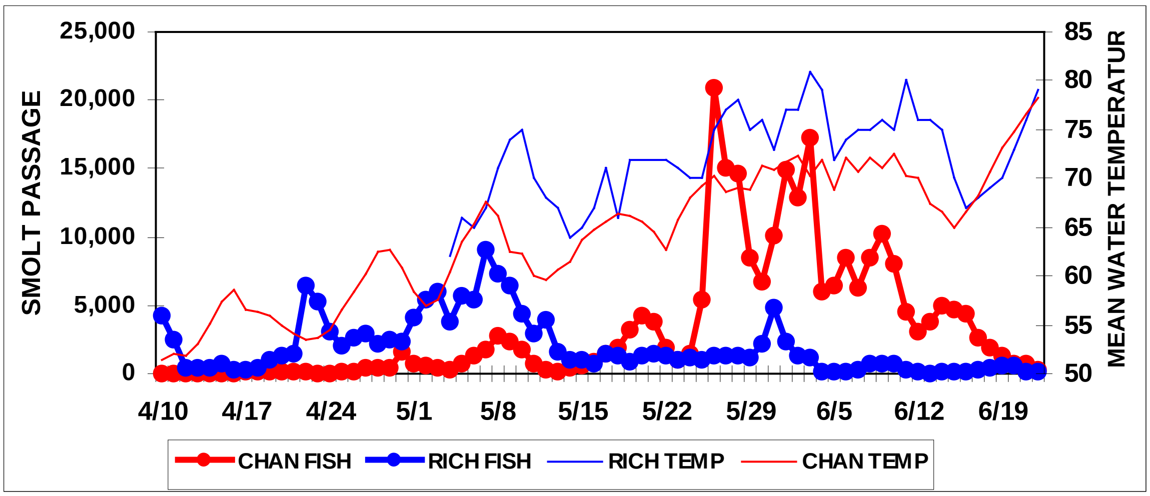


Figure 28. Estimated daily passage of fall chinook smolts at Chandler and near Richland (RM 8.0), and mean daily temperatures in degree F, April – June, 1992

The spawning run at Prosser begins in early September, peaks in late September, and is almost always totally finished by the second week of November (Figure 29). The variability in run-timing is related to flow, but not water temperature, and the flow/passage relationship is the opposite of that seen for spring chinook: higher flows accelerate passage (Figure 30).

The other piece of evidence is the disparity between simultaneous passage estimates at Chandler and in a screw trap fished near Richland in the lower Yakima (RM 8) in the spring of 1992. Figure 28 shows the estimated passage of fall chinook smolts at Chandler and at the Richland screw trap, lagged three days to adjust for travel time. Between May 26 and June 10, passage at Chandler averaged 10,538 fish per day, and totaled 174,624 fish. Comparable figures for the trap at Richland, 40 miles downstream, were 1,246 and 19,929[4],

[4] Note that the figures for the Richland screw trap are estimates of *passage*, not raw catch. Were generated by dividing daily catches by 0.045, the mean entrainment rate estimated from the recapture of marked fish.

respectively. This loss of fish is all the more remarkable in light of the fact about 70% of Yakima fall chinook spawn below Chandler. During this period, mean daily water temperatures at Richland averaged 76°F, and ranged from 72 to 81° F. Temperatures at Chandler averaged 71°F, ranging from 69 to 73°F. Evidently the smolts were able to cope with the temperatures at Chandler, but not those further downstream.

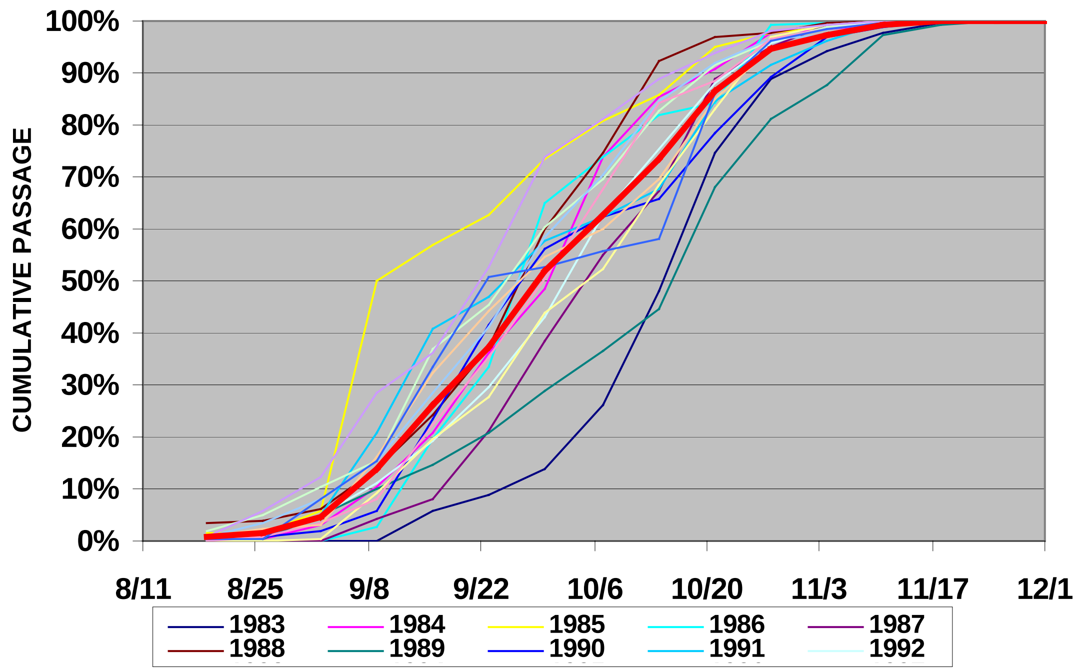


Figure 29. Timing of fall chinook adult and jack returns at Prosser Dam, 1983-1999

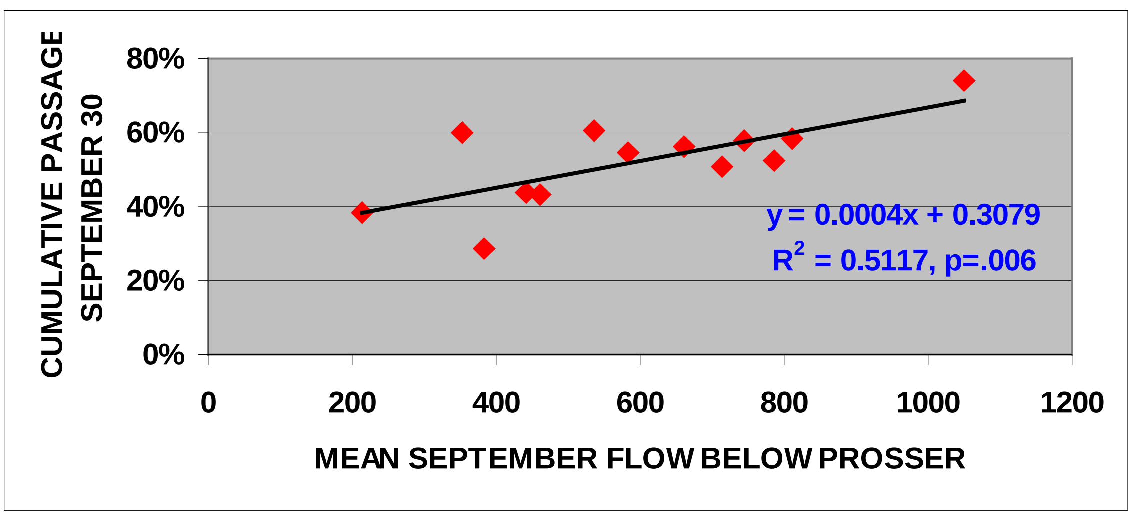


Figure 30. Relationship between mean September flow below Prosser Dam and cumulative passage of fall chinook adults on September 30, 1983 – 1999

Spawning is relatively concentrated above Prosser Dam, and appears to be synchronous in Marion Drain and the mainstem (Hubble, YN, pers comm 1999). It begins about the middle of October, peaks the first week of November, and is complete by the third week of November. Spawning in the lower mainstem, however, apparently includes some fish that spawn much later than the norm. WDF biologists operated a screw trap in the lower river in 1990 and captured 35 mm newly-emergent fry in May, when most fall chinook were 80-100 mm smolts (Busack et al., 1991). A spawning timing of late December or early January would be consistent with a May emergence.

There are striking differences in age distributions and sex ratios between the two fall chinook stocks. Curt Knudsen (WDFW, personal communication, 1992) estimated that the mean proportion of fish that were ocean age 1 through 4 in the mainstem stock was, respectively, 12%, 12%, 66% and 11%. By contrast, the age distribution for Marion Drain fish for the same ages was 48%, 46%, 6% and 0%. These figures represent the mean values observed in spawner/GSI surveys in 1989-1991, and incorporate corrections for sex- and size-related biases known to skew spawner survey data. Note that nearly half of the Marion Drain population consists of jacks (ocean age 1). Not surprisingly, sex ratios between stocks are equally divergent. The mean sex ratio in Marion Drain is 73% males and 27% females. By contrast, the sex ratio for the mainstem stock is 46% males and 54% females. These figures are based on spawner/GSI surveys in 1989 and 1990, and fish counts through the Horn Dam ladders and a picket weir in Marion Drain in 1992 (Busack et al., 1991; Seiler, 1992).

The highly skewed sex ratio in Marion Drain implies a correspondingly high spawners per redd ratio. The mean ratio observed in 1991 and 1992 was 9.3 spawners per redd. More importantly, the Marion Drain sex ratio implies a low reproductive potential and therefore, absent unusually high egg-to-adult survival rates or fecundity, low productivity. Although the fecundity of Marion fish has been estimated only for a handful of fish to date, it can be estimated from the mean size-at-age and sex-specific age data for females reported in Busack et al (1991), and the length fecundity relationship for spring chinook (Fast et al., 1991). The result of this calculation is 4,728 eggs/female. By contrast, the mean fecundity for mainstem females estimated at 6,106.

Typical emergence timing in the Yakima occurs from mid February to late April. A commonly accepted value for the cumulative thermal units for emergence of fall chinook is 1,600 TU's (Piper, 1987). Hubble (1997) used this value and historical temperature data from Marion Drain, Sunnyside Dam, Prosser Dam, and a regression for temperatures at Richland, to estimate emergence timing for fish spawned in Marion Drain and at various points along the mainstem. Marion Drain is totally fed by groundwater through the winter, and is often 10^0F warmer than the mainstem. Accordingly, emergence occurs earliest for Marion Drain fish, ranging from mid-February for eggs deposited by early spawners (mid October) to late March for late spawners (mid November). In the mainstem, emergence does not occur before late March and extends into the third week of April.

Productivity and Trends in Abundance

Table 18 summarizes the productivity parameters for a combined mainstem/Marion Drain fall chinook population spawning and rearing above Prosser Dam. The figures in the table entailed a number of assumptions relating to the proportion of Marion Drain and mainstem fish in the spawning escapement, spawning escapement in Marion Drain, etc, and so should be interpreted as rough approximations. The mean in-basin productivity is 120 smolts per spawner which, adjusting for the differing contributions of Marion Drain and mainstem fish over years, translates to a mean egg-to-smolt survival rate of 9.0% range 0.2 to 27.9%). For such a population to be self-sustaining, the mean smolt-to-adult survival rate must be at least 1/120 or 0.83%. In this analysis, the mean out-of-basin productivity (smolt-to-adult survival rate) is 1.7% (range 0.5 to 5.0%). If these rates were estimated exactly, their product – 2.07 -- would be the adult recruitment rate. Adult recruitment, estimated on the basis of adult counts, is 1.66, indicating perhaps the smolt-to-adult survival rate has been overestimated by an undetermined number of unmarked hatchery adults included in the wild spawning escapement. An adult recruitment rate of 1.66 is large enough to provide a measure of security for perpetuation of the population, but not large enough to sustain a significant fishery.

Table 18. Estimated natural production productivity parameters for the combined mainstem and Marion Drain Yakima fall chinook population spawning above Prosser Dam, 1983 – 2000

YEAR	WILD SMOLTS	ALL WILD SPAWNERS	SMOLT-TO-ADULT SURVIVAL	SMOLTS PER SPAWNER	ADULT RECRUITMENT RATE	MEAN TEMP (^{o}F)[a]
1983	103,521	380	0.58%		1.34	
1984	43,586	1331	1.17%	115	0.49	
1985	68,181	273	0.96%	**51**	1.39	
1986	33,380	731	1.14%	122	0.97	
1987	154,307	486	0.46%	210	2.23	69.7
1988	76,205	220	1.42%	142	6.35	69.5
1989	27,841	576	5.01%	120	1.74	67.6
1990	110,792	1161	0.91%	165	0.96	68.2
1991	55,083	823	2.03%	**37**	1.41	65.9
1992	253,455	1442	0.46%	261	0.83	74.2
1993	148,709	855	0.81%	92	1.34	69.0
1994	195,613	976	0.59%	184	1.20	72.3
1995	33,386	1241	3.51%	**22**	1.33	65.7
1996	6,512	1190		**5**		64.3
1997	35,578	992	5.02%	**26**		59.7
1998	406,814	1081		363		67.6
1999	45,702	1880		**40**		61.7
2000	175,912	1980		93		69.5
MEAN	**109,699**	**979**	**1.72%**	**120**	**1.66**	**67.5**

Mean water temperature at Prosser Dam over the period June 15 – July 15. A continuous thermal record of Prosser water temperature does not exist prior to 1987.

The seven brood years with the lowest smolt production rates (bold in Table 18) encountered very high water and presumably a measure of redd scouring during incubation. From earliest to most recent: brood year 1984 -- 15,936 cfs on January 27, 1984; brood year 1990 -- 22, 432 cfs on November 22, 1990; brood year 1994 -- 17,406 CFS on February 23, 1995; brood year 1995 -- 46,400 cfs on February 10, 1996; brood year 1996 -- 18,642 cfs on March 22, 1997; and brood year 1998 – 14,174 cfs on December 10, 1998. One might speculate that flows of this magnitude would not have had such an impact historically, when the river was free to expand laterally and spread its power over a much wider area.

One other relationship is apparent in Table 18: the adverse impact of late-spring water temperatures in the lower river on smolt-to-adult survival rates (Figure 30). Figure 30 plots smolt-to-adult survival against the mean water temperature at Prosser Dam over the period June 15 – July 15. The implication of this relationship is that, above 60 ^{o}F, every increase in water temperature of about 10^{o}F in the late spring will lower smolt-to-adult survival by about half.

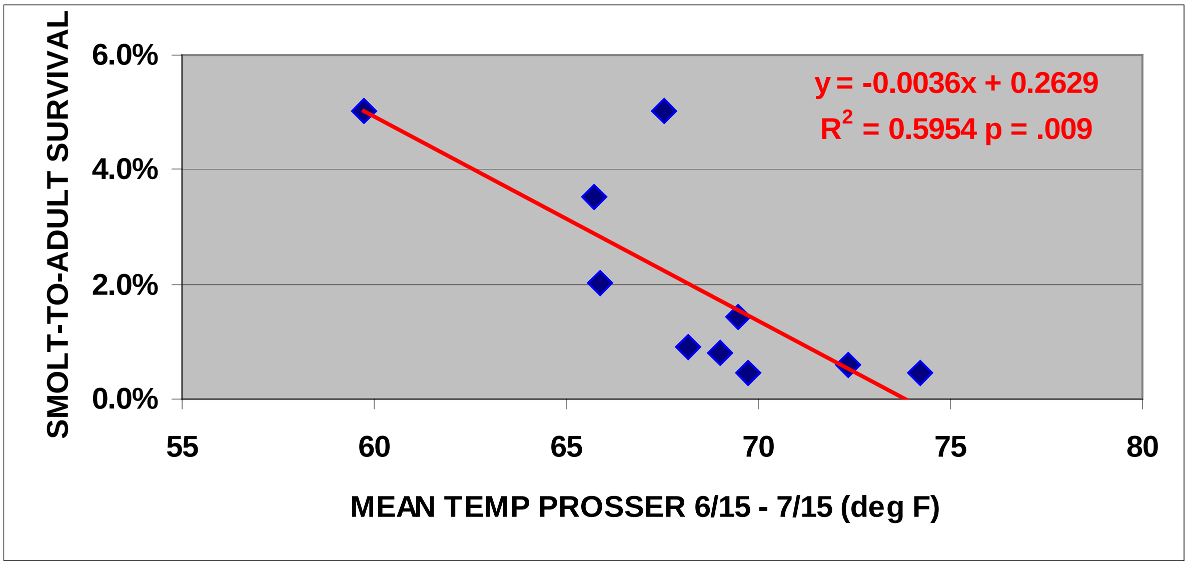


Figure 31. Relationship between smolt-to-adult survival for wild Yakima fall chinook and mean water temperature at Prosser Dam over the period June 15 - July 15

Summer Chinook

The Yakima River continued to support endemic summer chinook until the early 1970s. A total of three summer chinook redds were counted in the Yakima River between the confluence of the Naches River and Ahtanum Cr. in 1970 (YIN et al. 1990), the last year summer chinook redd surveys were conducted. Prior to the 1970s summer chinook spawned in the Yakima mainstem from approximately Marion Drain to Roza Dam, and in the lower Naches from its mouth to the Tieton confluence (RM 17.5). Kreeger and McNeil (1993) and Yakama Subbasin Plan (1990) estimate historical abundance at 86,000 and 100,000, respectively.

Summer Steelhead

Stocks and Distribution

Historically, steelhead were probably found wherever spring chinook were found, and in many other tributaries and reaches as well. Yakima steelhead spawn in intermittent streams (Hubble 1990), side channels of larger rivers (Pearsons et al.), and in smaller streams and streams with steeper gradients than are suitable for spring chinook or coho. Except possibly for streams at the highest elevations (USBOR 2000; Mullan), any reach in the basin with at least pocket of gravel at suitable depths and velocities can and probably will be used by steelhead spawners. Therefore it is probable that the historical spawning distribution of summer steelhead included virtually all accessible portions of Yakima Basin, with highest spawning densities occurring in complex, multi-channel reaches of the mainstem Yakima and Naches, and in third and fourth order tributaries with moderate (1-4%) gradients. Estimates of the size of the historical steelhead run range from 20,800[5] (Kreeger and McNeil 1993) to 100,000 (Smoker 1956).

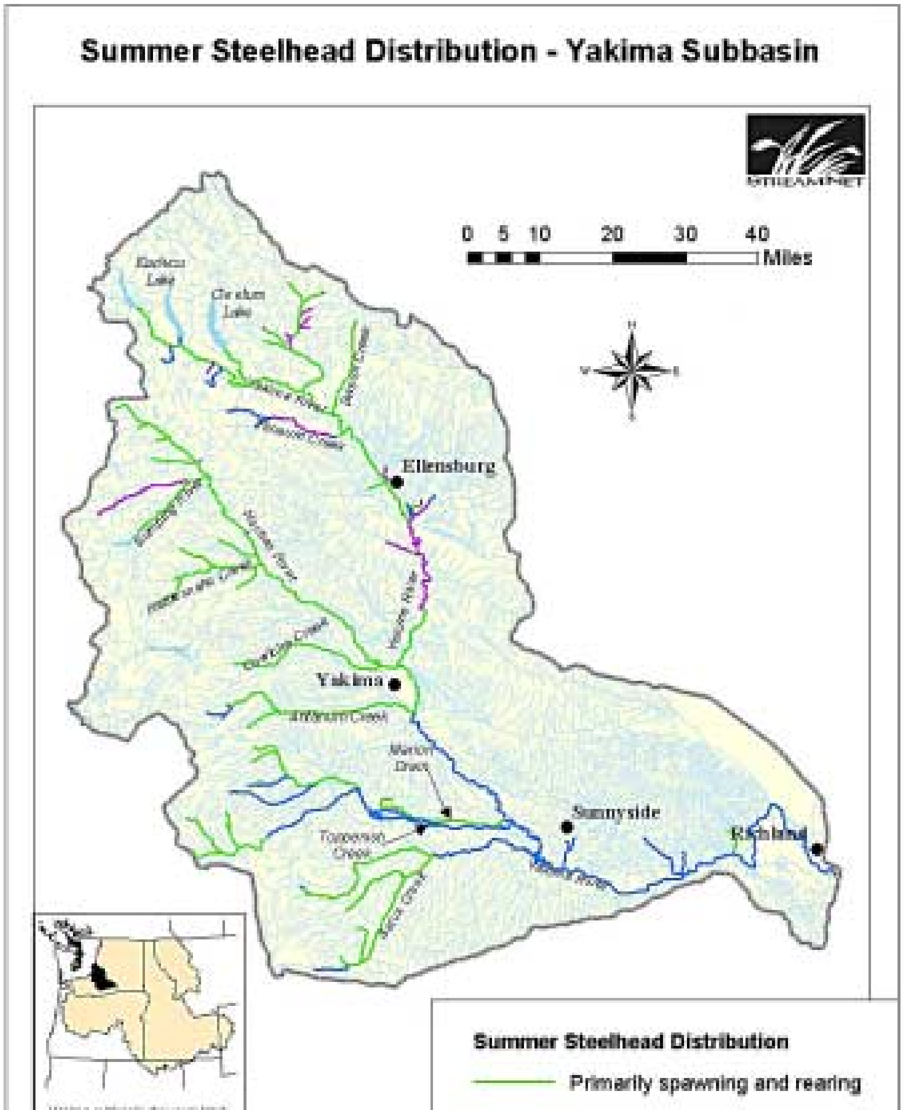


Figure 32. Summer steelhead distribution in the Yakima subbasin.

Table 19 summarizes the life history diversity, productivity and equilibrium abundance of a number of stocks of Yakima Basin steelhead under current and historical conditions as estimated by an initial EDT simulation made in the spring of 2000. The EDT simulation predicted a historical population of about 43,000 adults, a figure midway

---

[5] Mean of range estimated – 18,200 to 23,400.

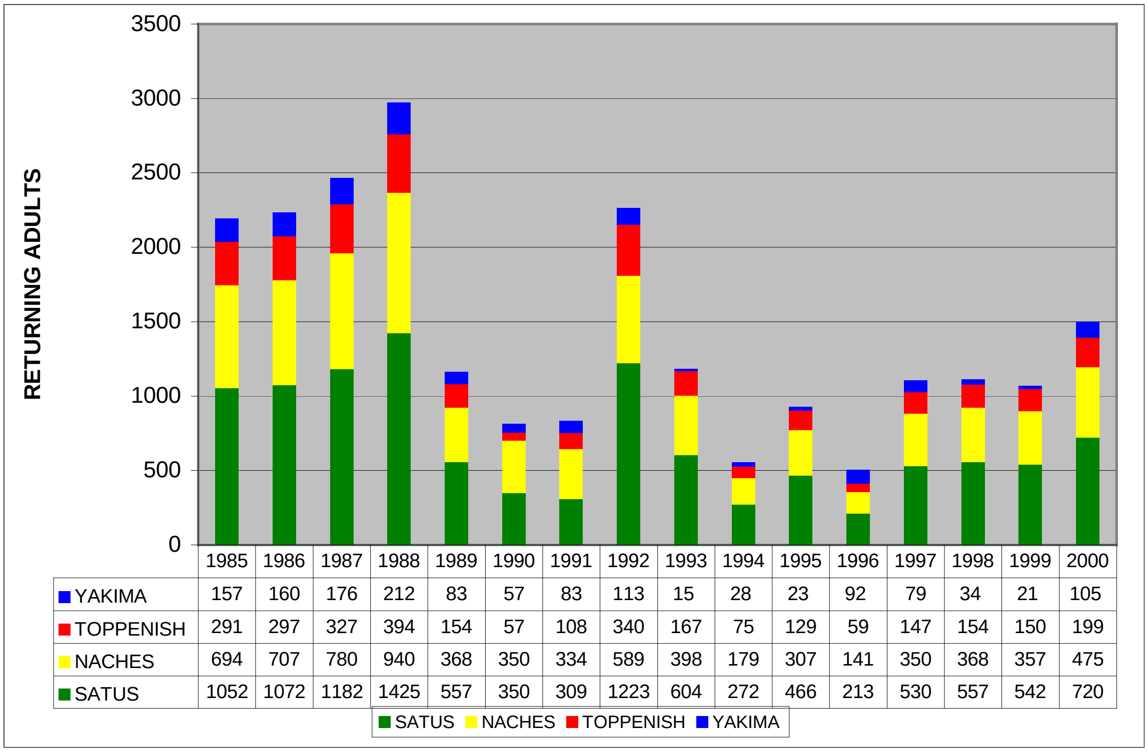
between the Kreeger and McNeil and Smoker estimates. It is noteworthy that the EDT-based estimates for *current* mean adult return and smolt production of about 1,000 and 61,000, respectively, agree rather well with recent observations.

Table 19. Estimated steelhead performance parameters in the Yakima subbasin as estimated by an initial EDT simulation made in April, 2000

Area	Sub Area	Life History Diversity	Productivity	Adult Equilibrium Abundance	Smolt Equilibrium Abundance
Historical Production					
Lower Yakima	Satus	52.0%	20.3	4,802	59,519
	Toppenish	68.0%	18.7	6,205	76,000
	Ahtanum	100.0%	7.6	1,745	20,580
	Lower Mainstem Yakima	52.0%	26.6	4,310	55,090
Naches	American	100.0%	18.1	1,419	15,513
	Naches excluding American	92.0%	16.7	11,016	124,339
Upper Yakima	Upper Yakima	91.0%	19.0	13,434	151,319
	Total			**42,931**	**502,359**
Current Production					
Lower Yakima	Satus	22.1%	2.0	288	18,028
	Toppenish	19.2%	1.5	173	11,891
	Ahtanum	8.7%	1.2	11	781
	Lower Mainstem Yakima	0.0%	0.0	0	0
Naches	American	58.8%	1.4	46	2,743
	Naches excluding American	11.3%	1.9	335	20,240
Upper Yakima	Upper Yakima	13.6%	1.2	125	7,242
	Total			**979**	**60,925**

The current distribution of Yakima Basin steelhead is much more restricted and spatially variable than it was historically. Well over half of the spawning occurs in Satus and Toppenish Creeks, with a smaller proportion in the Naches drainage and a much smaller proportion in the upper Yakima (the Yakima mainstem and tributaries upstream of the Naches confluence) (Hockersmith et al. 1995). See Figure 33 for current steelhead distribution. Current steelhead abundance is only about 1.3 to 6% of historical estimates, averaging 1,256 fish (range = 505 in 1996 to 2,840 in 1988) over brood years 1985[6] - 2000.

[6] Prior to the run of 1984-85, it was impossible to use the ladders at Prosser Dam to count adult steelhead, and estimates of runsizes before the 1985 brood are based on estimated catch and an assumed exploitation rate.



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
YAKIMA	157	160	176	212	83	57	83	113	15	28	23	92	79	34	21	105
TOPPENISH	291	297	327	394	154	57	108	340	167	75	129	59	147	154	150	199
NACHES	694	707	780	940	368	350	334	589	398	179	307	141	350	368	357	475
SATUS	1052	1072	1182	1425	557	350	309	1223	604	272	466	213	530	557	542	720

Figure 33. Estimated returns by stock of Yakima Basin summer steelhead, 1985 – 2000

In 1989, Yakima steelhead returns declined sharply from the 2,000- to 3,000-fish runs seen in the late 1980's. Except for 1992, abundance has fluctuated around 1,000 fish since 1989.

Table 19 indicates that all areas were much more productive historically than currently, and that a much larger proportion of life histories were viable. Also notable is the fact that the upper Yakima is identified as the area supporting the largest steelhead population in historical times, whereas now it supports the smallest.

There are a number of reasons to believe that the historical upper Yakima was in fact the largest steelhead-producing area, and a number of factors can be cited as contributing to its decline. The upper Yakima clearly should have been a major steelhead producer because its total area is greater than any other, and it provided habitat types including complex, alluvial mainstem reaches and third- and fourth-order tributaries (e.g., Wilson, Manastash and Taneum Creeks) that still provide good steelhead habitat where they are not affected by irrigation withdrawals and agricultural development (Johnston, 1989). Just as clearly, several factors played a large role in the decline of steelhead production in the upper Yakima. The most severe of these factors were the structural simplification of most of the anastomosing reaches of the mainstem, the partial or total blockage of spawning tributaries by irrigation diversion dams, and the wholesale entrainment of smolts in tributary and mainstem irrigation diversions. Another irrigation-related impact was the release of large volumes of water from storage reservoirs in the summer, when steelhead fry are just emerging and are incapable of holding position against high flows. In a river like the Yakima, swept clean of large woody debris by 30 years of log drives, significant downstream displacement of fry to less suitable lower river areas is probable. Stranding of fry and parr in shallow side channels during frequent, artificial flow fluctuations is another probable irrigation-related impact.

The completion of Roza Dam in 1941 is an impact that negatively distinguishes the upper Yakima from all other steelhead production areas. Between 1941 and 1959, the ladder at Roza Dam was dewatered whenever the pool was lowered at the end of the irrigation season. During this period, the pool was down, on average, from October 19 through March 17 (USBOR HYDROMET data). This dewatering made the upper Yakima inaccessible to most fall-run steelhead, and provided only a narrow window of opportunity for spring-run fish needing to reach spawning areas miles upstream by April or May. A new ladder was installed in 1989 which allows full access to the upper Yakima so long as the pool is either completely up or completely down.

There are other factors that probably affect steelhead production in the upper Yakima at the present time. Some are the genetic or behavioral legacy of the long period of reduced access, and some are the outcome of intra-specific competition in the existing, non-normative system.

In light of the fact that steelhead spawners were almost totally excluded from the Yakima Basin above Roza Dam for 18 years, it is rather surprising that the area produces any steelhead at all. Are steelhead in the process of recolonizing the upper Yakima, now that full adult access has been restored? Are upper Yakima steelhead the subdominant anadromous ecotype of an *O. mykiss* population selected for residency by many years of restricted adult access and low smolt-to-adult survival? And what role does relative rainbow/steelhead productivity play in the issue? Given the high growth rates and favorable survival rates (after the fry stage) that characterize upper Yakima *O. mykiss* populations (Pearsons et al 1994), the productivity (adult progeny/spawner) of resident fish must be considerably greater than for anadromous fish, which must survive two to three more years, including a round-trip through the lower Yakima River, before reaching reproductive maturity. Indeed, in an initial allopatric EDT simulation of rainbow and steelhead production in the upper Yakima, the productivity of the rainbow population was over three times larger than the productivity of steelhead. In this light, it seems inevitable that that the composite rainbow/steelhead population in the upper Yakima should be weighted toward the resident ecotype at this time.

These questions have not yet been answered. This uncertainty is difficult because different answers entail different kinds of enhancement programs. One need only consider two logical alternatives and their implications to get a sense of the importance surrounding these issues. First, suppose anadromy is strongly heritable and the existing upper Yakima "steelhead" population has been selected for residency. In that case, a local-stock supplementation program would be futile: almost all "smolts" would "residualize". Even restoration of normative habitat conditions would fail to increase steelhead abundance until enough time had elapsed for the newly-favored anadromous genotype to become dominant. In this case, a better approach would be to introduce "real steelhead" from a nearby population (e.g., Naches stock) in concert with habitat projects geared toward improving egg-to-smolt survival. If, on the other hand, anadromy is determined largely by environmental conditions, the appropriate response is to restore conditions that favor smolt production over sexual maturation, and that increase smolt-to-adult survival.

At the core of these post-passage-restoration issues lies the fundamental question of the mechanism that determines residency and anadromy in *O. mykiss* populations.

Surprisingly little research has been done in this area. It is known that some areas support sympatric populations of steelhead and rainbow that are reproductively isolated while others are not: steelhead breed with rainbow and vice versa (Zimmermann 2000). In addition many rainbow trout populations have been observed to produce occasional smolts, just as many steelhead populations occasionally produce individuals that live out their lives entirely in fresh water. What is not known is the relative importance of heredity and the environment: specifically whether or under what circumstances environmental conditions can tip a genetically equipotential population from a stable equilibrium dominated by one ecotype to a stable equilibrium dominated by the other.

While this issue and its implications are most serious in the upper Yakima, they are important wherever resident and anadromous *O. mykiss* coexist. Resident and anadromous ecotypes are both present in the Naches drainage (Pearsons 1996) and probably in the middle Yakima (the Yakima mainstem from Roza Dam to Sunnyside Dam), but only the steelhead ecotype seems to be present in Satus and Toppenish Creeks. The latter assertion is based on the fact that very few three-year-olds and no four-year-olds were found among large numbers of juveniles sampled in the 1980s and 1990s, and the fact that the few three-year-olds observed were very smolt-like in appearance.

The genetic composition of historical steelhead populations in the Yakima Basin is unknown, but a considerable amount is known about the genetic structure of the existing populations of rainbow and steelhead in the basin. Busack and Phelps (1996) performed a number of electrophoretic analyses on rainbow trout and steelhead of both wild and hatchery origin collected at 14 sites over six years. On the basis of a large number of paired comparisons of allozyme frequencies, Busack and Phelps determined there are four genetically distinct population of wild steelhead in the basin: an upper Yakima stock, a Naches stock, a Satus Creek stock and a Toppenish Creek stock. They also determined from admixture analyses that wild rainbow and steelhead from a number of locations in the upper Yakima interbreed. Although a comparable analysis of wild Naches trout and steelhead was not performed, it was determined that hatchery trout and Naches steelhead have interbred, as have hatchery trout and wild steelhead in the upper Yakima. Wild Satus and Toppenish Creek steelhead, on the other hand, showed no evidence of interbreeding with hatchery trout or steelhead.

These findings are consistent with the fact over three million hatchery trout (primarily South Tacoma and Goldendale stock) have been planted in the upper Yakima and Naches since 1950, and that 1.6 million hatchery steelhead (primarily Skamania stock) have been planted in the upper Yakima and Naches since 1961. Hatchery rainbow trout have never been released in either Satus or Toppenish Creek and, except for one release of 25,000 hatchery-reared Yakima-stock smolts made in Toppenish Creek in 1989, the same is true for hatchery steelhead.

In summary, Yakima steelhead populations comprise four genetic stocks, two of which, the upper Yakima and Naches stocks, are sympatric with wild resident trout. Both of these stocks interbreed with both hatchery and wild rainbow trout. Finally, both wild Naches and upper Yakima steelhead have interbred with Skamania stock hatchery steelhead, although no wild sample indicated more than a 20% infusion of Skamania genes (Busack and Phelps 1996).

Hockersmith et al (1995) successfully monitored 105 radiotagged steelhead to spawning over brood years 1990 – 1992. Because high and turbid water in the Naches and

Yakima mainstem during steelhead spawning precludes redds counts, this radiotagging data is the only means of estimating the stock composition of the run. The mean percent over all three brood years of radiotagged fish that spawned in Satus Creek, Toppenish Creek, the Naches Subbasin and the upper Yakima mainstem was 48.0%, 31.6%, 13.3% and 7.1%, respectively. These percentages, in combination with adult steelhead counts at Prosser Dam (brood years 1985 – 2000) and Roza Dam (brood years 1993 – 1996 and 1998 – 2000), were used to estimate the stock-specific total returns for steelhead depicted in Figure 33.

Yakima Basin summer steelhead have been included in the Middle Columbia River (MCR) Evolutionarily Significant Unit (ESU; Busby et al. 1986), which was listed under the Endangered Species Act (ESA) as “threatened” on March 25, 1999 (64 FR 14517). The MCR USU includes all wild populations of summer steelhead in the Columbia River and its tributaries from the Wind River to the Yakima River – specifically, the Wind, Deschutes, Yakima, John Day and Umatilla Rivers. The inclusion of Yakima Basin steelhead in the MCR ESU was based on similarities of life history and habitat as well as electrophoretic similarities (Phelps et al. 1994).

Life History and Demographics

Tables 20 and 21 summarize sex-specific age data for Yakima Basin summer steelhead collected at Prosser Dam for brood years 1990 – 1992. As Prosser Dam lies below almost all spawning areas, the data collected there represents a composite across all four stocks. Age was determined by scale analysis. This is the most comprehensive age data yet collected for Yakima steelhead, although adults collected as broodstock in 1986 and 1987 were also aged, as were a small number of adults sampled in the 1983 sport fishery. Over all collections and both sexes, the mean proportion of 1-, 2- and 3-salt fish are 52.4%, 44.2% and 3.3%. Total age, also averaged over all collections and both sexes, for total ages three through seven, is 8.0%, 49.1%, 38.2%, 4.3% and 0.4%, respectively. The mean sex ratio over the 1990-1992 brood years (the only dataset in which both sexes were accounted for) was 68.5% female and 31.5% male.

Table 20. Sex-specific ocean and total ages, Yakima Basin summer steelhead collected at Prosser Dam, brood years 1990 – 1992 (all stocks)

BROOD YEAR AND AGES		FRACTION OF MALES THAT ARE AGE x	FRACTION OF FEMALES THAT ARE AGE x	FRACTION OF ALL FISH THAT ARE AGE x MALES	FRACTION OF ALL FISH THAT ARE AGE x FEMALES	FRACTION OF ALL FISH THAT ARE AGE x
1990	1 SALT	66.7%	62.5%	18.2%	45.5%	63.6%
	2 SALT	16.7%	37.5%	4.5%	27.3%	31.8%
	3 SALT	16.7%	0.0%	4.5%	0.0%	4.5%
	Total	**100.0%**	**100.0%**	**27.3%**	**72.7%**	**100.0%**
	Total age 3	0.0%	6.3%	0.0%	4.5%	4.5%
	Total age 4	66.7%	56.3%	18.2%	40.9%	59.1%
	Total age 5	16.7%	37.5%	4.5%	27.3%	31.8%
	Total age 6	16.7%	0.0%	4.5%	0.0%	4.5%
	Total age 7	0.0%	0.0%	0.0%	0.0%	0.0%
	Total	**100.0%**	**100.0%**	**27.3%**	**72.7%**	**100.0%**
1991	1 SALT	50.0%	30.0%	10.5%	23.7%	34.2%
	2 SALT	50.0%	63.3%	10.5%	50.0%	60.5%
	3 SALT	0.0%	6.7%	0.0%	5.3%	5.3%

BROOD YEAR AND AGES		FRACTION OF MALES THAT ARE AGE x	FRACTION OF FEMALES THAT ARE AGE x	FRACTION OF ALL FISH THAT ARE AGE x MALES	FRACTION OF ALL FISH THAT ARE AGE x FEMALES	FRACTION OF ALL FISH THAT ARE AGE x
	Total	**100.0%**	**100.0%**	**21.1%**	**78.9%**	**100.0%**
	Total age 3	25.0%	13.3%	5.3%	10.5%	15.8%
	Total age 4	25.0%	23.3%	5.3%	18.4%	23.7%
	Total age 5	50.0%	56.7%	10.5%	44.7%	55.3%
	Total age 6	0.0%	3.3%	0.0%	2.6%	2.6%
	Total age 7	0.0%	3.3%	0.0%	2.6%	2.6%
	Total	**100.0%**	**100.0%**	**21.1%**	**78.9%**	**100.0%**
1992	1 SALT	74.4%	56.5%	26.9%	36.1%	63.0%
	2 SALT	23.1%	40.6%	8.3%	25.9%	34.3%
	3 SALT	2.6%	2.9%	0.9%	1.9%	2.8%
	Total	**100.0%**	**100.0%**	**36.1%**	**63.9%**	**100.0%**
	Total age 3	15.4%	7.2%	5.6%	4.6%	10.2%
	Total age 4	66.7%	63.8%	24.1%	40.7%	64.8%
	Total age 5	15.4%	26.1%	5.6%	16.7%	22.2%
	Total age 6	2.6%	2.9%	0.9%	1.9%	2.8%
	Total age 7	0.0%	0.0%	0.0%	0.0%	0.0%
	Total	**100.0%**	**100.0%**	**36.1%**	**63.9%**	**100.0%**

Table 21. Percent of radiotagged steelhead observed spawning in various tributaries and reaches, brood years 1990 – 1992

STOCK	BROOD YEAR			
	1990	1991	1992	MEAN ALL YEARS[b]
SATUS	43%	37%	54%	48.0%
NACHES	43%	40%	26%	31.6%
TOPPENISH[a]	7%	13%	15%	13.3%
YAKIMA	7%	10%	5%	7.1%

a) Includes fish spawning in Marion Drain, an irrigation return connected to Toppenish Creek. b) Estimated as the sum across years of fish spawning in tributary x divided by sum across years of all fish spawning in all tributaries. (Hockersmith et al 1995)

Table 22 summarizes what is known about stock-specific smolt ages. Except for the Satus stock, the age composition of Yakima juveniles identified as smolts is fairly typical of what is seen in Washington and Oregon, with 10-14% age-1 fish, 71-85% age-2 fish and 5-18% age-3 fish. Also typical is the change in smolt ages as reflected in adults, which in this case show mean freshwater ages ranging from 0-17%, 83-100% for ages 1 and 2, respectively, and no age-3 smolts. The downward shift in the smolt age distribution as reflected by adults relative to juveniles is usually attributed to a combination of three factors: the likelihood that some of both the age-3 and age-1 fish were not steelhead, but trout; the likelihood that some of the age-1 fish were actually steelhead parr migrating into larger waters for their final year of rearing; and the likelihood that some of the true age-1 steelhead smolts suffered higher mortality rates because of the size-related vulnerability to a wider range of predators. The Satus stock is, however, unusual both in having such a large percentage of age-1 smolts and in their surviving to returning adult. Presumably this is due to the warm temperatures of Satus Creek, in which steelhead fry emerge in May, and in its being so productive that 40-50% of steelhead juveniles reach smolt status as yearlings.

Table 22. Estimates of ages of Yakima steelhead smolts by stock as determined from scales sampled from smolts and scales sampled from adults

STOCK	Smolt age determined from smolts			Smolt age determined from adults		
	1	2	3	1	2	3
Satus	42%	57%	1%	37%	63%	0%
Naches	14%	75%	12%	10%	90%	0%
Toppenish	10%	85%	5%	0%	100%	0%
U. Yakima	11%	71%	18%	17%	83%	0%
Basin-wide	41%	56%	4%	23%	77%	0%

Busack et al 1991; YN, unpublished data, 2001

Yakima steelhead are relatively small, as might be expected for fish that are 52% 1-salts. The mean fork length of the fish sampled in the 1990 – 1992 broods was 66.5 cm (about 26 inches), and the mean weight was about 3.0 kg (about 6.7 lbs). In spite of their size, Yakima steelhead are quite fecund. Mean fecundity for fish collected as broodstock in brood years 1986, 1987, 1989, and 1990-1993 was 5,100 eggs. The duration of the successive freshwater life stages of all four stocks of Yakima summer steelhead is summarized in Figure 34. (Note: the duration of life stages for age-3 smolts is identical to that for age-2 smolts.)

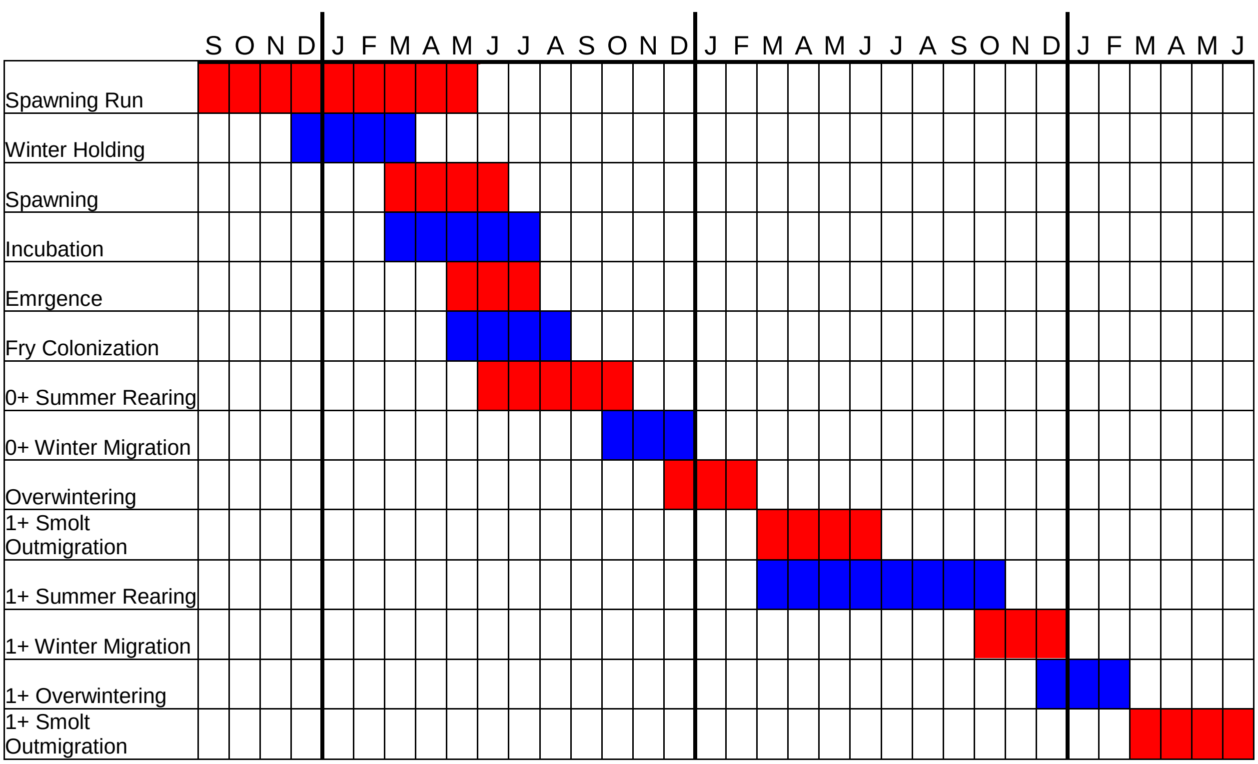


Figure 34. General duration of successive life stages in for Yakima Basin summer steelhead (all stocks)

Steelhead adults begin passing Prosser Dam in September, cease movement during the colder parts of December and January, and resume migration from February through June (Figure 35). The run has two peaks, one in late October, and one in late February or early March. The relative numbers of wild fish returning during the fall and winter-spring migration periods varies from year to year, perhaps depending on the duration of a “thermal window” in the fall.

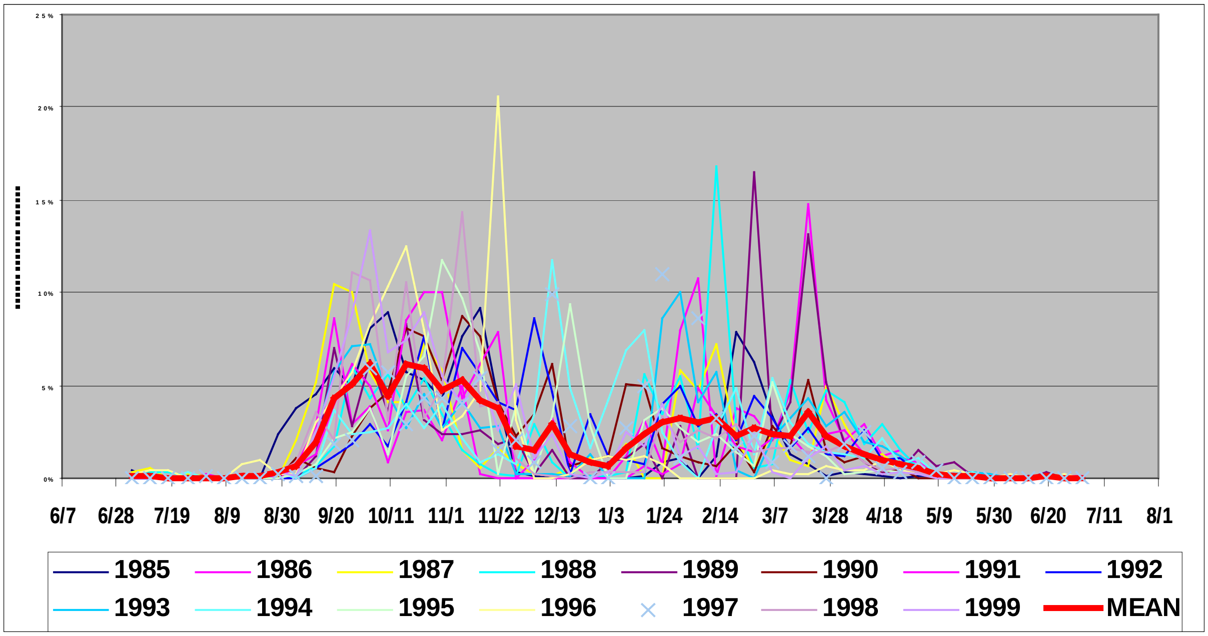


Figure 35. Weekly percent passage of wild adult summer steelhead at Prosser Dam, 1985-1999

Studies of steelhead radiotagged and released at Prosser Dam over the years 1990 - 1993 (Hockersmith et al. 1995) indicate that most “fall-run” steelhead spawners overwinter in the mainstem Yakima, in reaches with deep holes and low velocity. About 25% hold below Prosser Dam , 60% between Prosser Dam and Sunnyside Dam (many in the vicinity of the Satus Creek confluence) and 6% between Sunnyside Dam and Roza Dam. Only about ten percent of the fish held in Satus Creek, Toppenish Creek, Marion Drain the lower Naches River, or the upper Yakima combined.

The final migration to the spawning grounds begins between January and May, generally with fish that will eventually spawn in lower elevation tributaries beginning to move earlier. There is some evidence that the cue triggering this final run is thermal, as very few fish ascended Satus Creek during mid-winter floods, and virtually none of the eventual Naches spawners began moving until water temperatures reached 3o C (Hockersmith et al. 1995).

Most Yakima steelhead are tributary spawners. Over 90% of the steelhead tagged in the Hockersmith study spawned in the Naches River and tributaries, Satus Creek or Toppenish Creek.

In Satus Creek, 70 percent of the spawning occurs in three areas: Satus Creek between Logy and Bull Creek (RM 23.6 – 36.0), in Dry Creek (confluence at Satus RM 18.7) and in Logy Creek (confluence at Satus RM 23.6). The remainder occurs in smaller tributaries and various Satus Creek reaches above Dry Creek (confluence at Satus RM 8.0), including 15% that spawn in tributaries that regularly go dry by mid to late May.

Spawning timing is the earliest in the basin, and is relatively protracted. Hockersmith et al. believed spawning began in February and YN biologists have observed spawning in mid March. The peak is in early April and with the last activity occurring in early May.

In the Naches, 69% of spawning occurs in only two reaches, the Naches between Cowiche Cr. (RM 2.7) and the Tieton River (RM 17.5), and the Naches between Rattlesnake Creek (RM 27.8) and the Little Naches River (RM 44.6). The Bumping River (confluence at Naches RM 44.6) and the Naches between the Tieton River and Rattlesnake Creek each support 11.5%, and Rattlesnake Creek and the Naches from the mouth to Cowiche Creek each support 3.8%. Importantly, about 43% of all spawning occurs below the Tieton River confluence, and progeny are therefore subject to the most severe impacts of flip-flop. No spawning has been observed in the Tieton River or the American River. The lack of spawning in the Tieton is to be expected, in light of the fact it has been swept virtually clean of spawning gravel, but the absence of steelhead from the American River, one of the most pristine streams in the basin, is puzzling. In the Naches as elsewhere in the basin, spawning begins earliest at the lowest elevations. From radiotagging data and records of the first observations of steelhead fry, steelhead spawn in the lower Naches (below Tieton) and its tributaries from early March through mid May. In the upper Naches, the spawning period is from late March through late May. In the higher elevation tributaries of the upper Naches (the Little Naches River, Bumping River, Rattlesnake Creek), spawning occurs from late April through late May, with peak in early May.

Toppenish Creek drains a large watershed (~650 mi2), but only the upper half of the drainage is used for spawning. Over 57% of the steelhead spawning in Toppenish Creek occurs from Willy Dick Creek (RM 48.5) to Panther Creek (RM 69.2); the remainder occurs in the major tributary to Toppenish Creek, Simcoe Creek, which is also located relatively high in the drainage (confluence at Toppenish RM 32.7). In upper Toppenish Creek, about 60% of the spawning occurs in Toppenish Creek itself, with the remainder in two small tributaries. All but 9.7% of the spawning in the Simcoe drainage occurs in a number of small tributaries. Several of the upper Toppenish and Simcoe Creek tributaries are intermittent. Marion Drain is an irrigation return which parallels Toppenish Creek and into which Toppenish Creek water is diverted. It is probable that all of the steelhead that spawn in Marion Drain are or were ancestrally Toppenish Creek fish, lured into a cul de sac by Toppenish Creek water. The Toppenish Creek stock would be about 15% larger if the Marion Drain fish are included. Steelhead spawn in Toppenish Creek from early March to early May with a peak in early April.

Over 70% of the handful of radiotagged fish that have been called “upper Yakima spawners” actually spawned in the Yakima mainstem spawn below Roza Dam – between Roza Dam and Ahtanum Creek (RM 106.9). Of the remaining 30%, 14% spawned in the Teanaway River and its forks and the remainder in various upper Yakima tributaries and mainstem reaches. As nearly as can be determined spawning occurs in the middle Yakima (the Yakima between Roza Dam and Sunnyside Dam), the upper Yakima mainstem and higher elevation upper Yakima tributaries according to the following approximate schedule:

- Middle Yakima: late February through early April, peak in late March.
- Upper Yakima mainstem: in Yakima Canyon (including Umtanum and Wilson/Naneum Creeks), late March to mid May with a peak in late April, and above the Yakima Canyon from mid April to late May with a peak in early May.

• Upper Yakima tributaries (Big Cr., Teanaway River, Swauk Cr., Taneum Cr., Manastash Cr.): late April through early June, with a peak in late May.

Using an estimate of 1,300 TU's for 50% emergence, known or assumed spawning dates, existing water temperature data (when available), and field observations of newly emerged fry (fry 25-30 mm long), fry emergence probably occurs at the following times in the following places:

- Satus Creek: early May to early June.
- Toppenish Creek: late May through early July.
- Lower Naches and Cowiche: early June through mid July.
- Upper Naches: mid June through mid July.
- Upper Naches tribs: late June through late July.
- Middle Yakima and tribs: early June through early July.
- Upper Yakima mainstem in Yakima Canyon (including Umtanum Cr and Wilson/Naneum): early June through early July.
- Upper Yakima mainstem above the Yakima Canyon: mid June through late July.
- Upper Yakima tribs: late June through early August.

Pre-smolt rearing migrations are less well understood for steelhead than they are for spring chinook. The presence of steelhead juveniles in small tributaries, sometimes in high densities, throughout the summer indicate that the fish are less inclined to migrate downstream for early rearing than spring chinook. However, *O. mykiss* juveniles are found in substantial numbers in the Yakima Canyon far from spawning areas, so a gradual downstream dispersal of fry and parr obviously occurs.

As observed at the Chander smolt trap, a lower proportion of steelhead juveniles migrate to the lower river in the winter than do spring chinook. Substantial winter migrations do occur however, albeit perhaps not over so great a distance. In the winter of 1990-91 and the following spring, the YN operated a smolt trap on Satus Creek just below the Logy Creek confluence. A third more steelhead juveniles moved past the Satus Creek trap that winter than the following spring. A distinct pulse of steelhead juveniles were also seen in the late fall at a smolt trap operated at Wapatox Dam from 1984 – 1990, although icing always forced closing of the trap by early December at the latest, precluding estimates of the relative magnitude of spring and winter movements. At Chandler virtually all winter movement occurs in February, more than a month after the typical peak of spring chinook movement.

At Chandler, the steelhead smolt outmigration begins in late February and ends in mid June (Figure 36). Statistically, the mean date of passage for the 10^{th}, 50^{th} and 90^{th} percentiles of the outmigration are April 6, May 1 and May 19. These are almost exactly the same dates as for spring chinook, which are, respectively, April 6, April 23 and May 20. Comparison of Figures 16 and 36 suggest that the outmigration timing of spring chinook is more variable interannually than steelhead, even though their means are similar. In addition the timing of the steelhead outmigration is not accelerated by higher cumulative thermal units the preceding winter, as is the case with spring chinook.

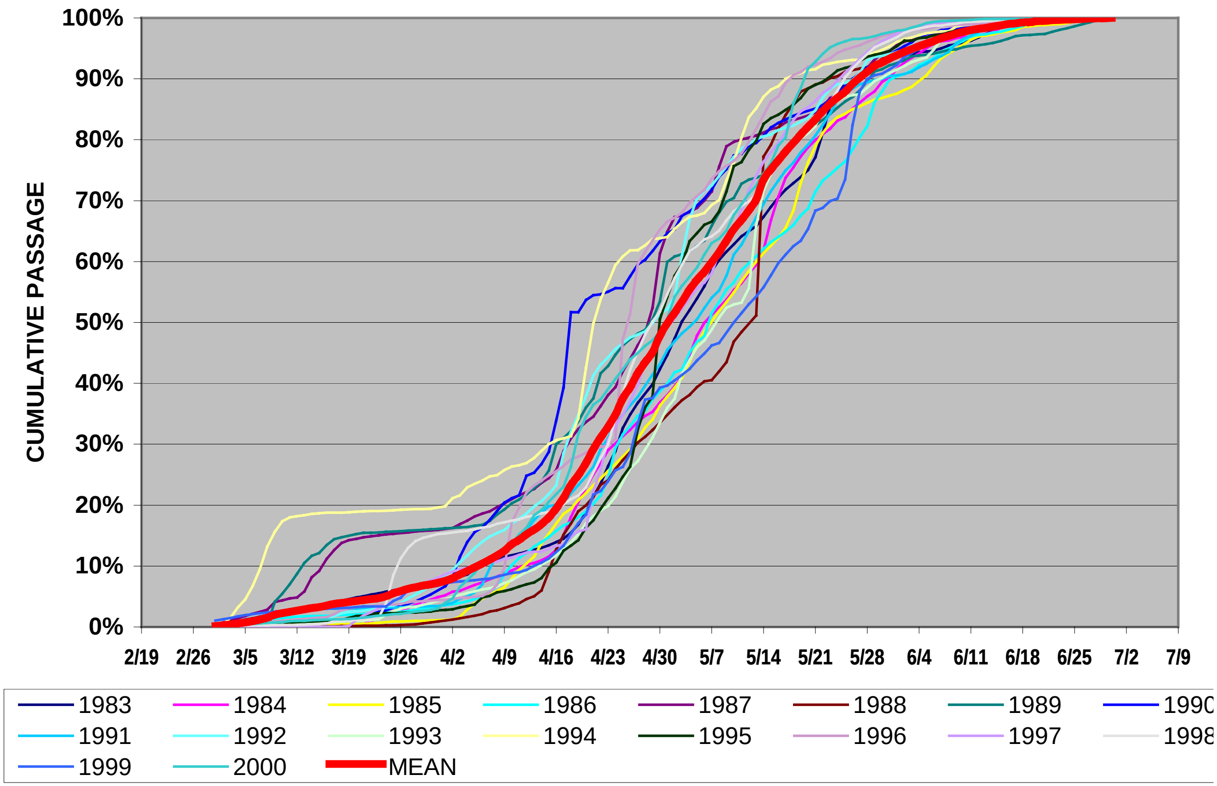


Figure 36. Cumulative passage of steelhead smolts at Chandler smolt trap, 1983-2000

The midpoint of outmigration at Wapatox is also generally around the first week in May. Given the distances involved and smolt migration rates observed, the midpoint of the outmigration of Naches steelhead would not occur at Prosser for at least another week. Thus, as many as half the smolts leaving the Naches must negotiate the perilous lower river in late May and early June.

Productivity and Trends in Abundance

Table 23 summarizes the productivity parameters of the composite Yakima steelhead population: smolts per spawner, smolts-to-adult survival and adult recruitment rate. Both the smolts and the adults in Table 23 were counted at Prosser Dam. Over the period of record, smolt-to-adult survival ranges from 0.8 to 7.4%, with a mean of 3%, and smolt productivity ranges from 8.0 to 222.8, with a mean of 62.4. In six of the 11 years for which adult recruitment rate can be estimated, recruitment was less than 1.0. The adult recruitment rate ranged from 0.31 to 1.79, with a mean of 0.97, a value that justifies the listing of the species under the Endangered Species Act.

Table 23. Steelhead smolt production, adult return and spawning escapement, smolts/returnees and returnees/smolt estimates

Year	Total Smolts	Adult Return Hatchery	Adult Return Wild	Adult Return Total	Wild Adults from Smolts Yr X	Brood Year Escapement (Wild + Hatch)	Smolts from Brood Year Escapement	Smolt to Adult Survival	Smolts per Spawner	Adult Recruitment Rate
1983	81,640	N.D.	N.D.	N.D.	1,818			2.23%		
1984	97,920	N.D.	N.D.	N.D.	2,987			3.05%		
1985	65,735	0	2,194	2194	2,249	689	107,329	3.42%	155.78	1.44
1986	120,591	0	2,235	2235	1,858	1408	101,232	1.54%	71.90	0.67
1987	109,934	0	2,465	2465	879	1822	39,168	0.80%	21.50	0.42
1988	70,961	239	2,601	2840	925	2496	31,330	1.30%	12.55	0.75
1989	26,620	96	1,066	1162	1,040	864	22,654	3.91%	26.22	1.06
1990	23,075	87	727	814	1,697	539	31,169	7.36%	57.83	1.28
1991	22,983	104	730	834	845	782	20,054	3.68%	25.64	0.84
1992	36,225	251	2,014	2265	661	2095	16,824	1.82%	8.03	0.31
1993	17,339	80	1,104	1184	657	1089	20,017	3.79%	18.38	0.78
1994	18,738	14	540	554	630	551	30,115	3.36%	54.66	1.79
1995	17,715	98	820	918	881	918	63,729	4.98%	69.42	1.29
1996	45,814	54	451	505	996	485	108,036	2.17%	222.76	
1997	69,450	145	816	961	1,215	961	91,962	1.75%	95.69	
1998	117,765	165	948	1113		1,113	36,697		32.97	
1999	70,293	52	1,018	1070		1,070				
2000	41,361	52	1,448	1500		1,500				
MEAN	**58,564**	**86**	**1357**	**1444**	**1,289**	**1,149**	**51,451**	**3.01%**	**62**	**0.97**
MAX	**120,591**	**251**	**2601**	**2840**						
MIN	**17,339**	**0**	**451**	**505**						

Existing data suggests density-dependence is a significant depressing factor on steelhead productivity as observed at Prosser Dam. Figures 37 and 38 show a significant, curvilinear, inverse relationship between adult recruitment rate and smolt productivity as a function of the number of brood year spawners. It is likely that this relationship reflects the fact that the majority of production under current conditions is restricted to Satus and Toppenish Creeks, which obviously have a limited carrying capacity.

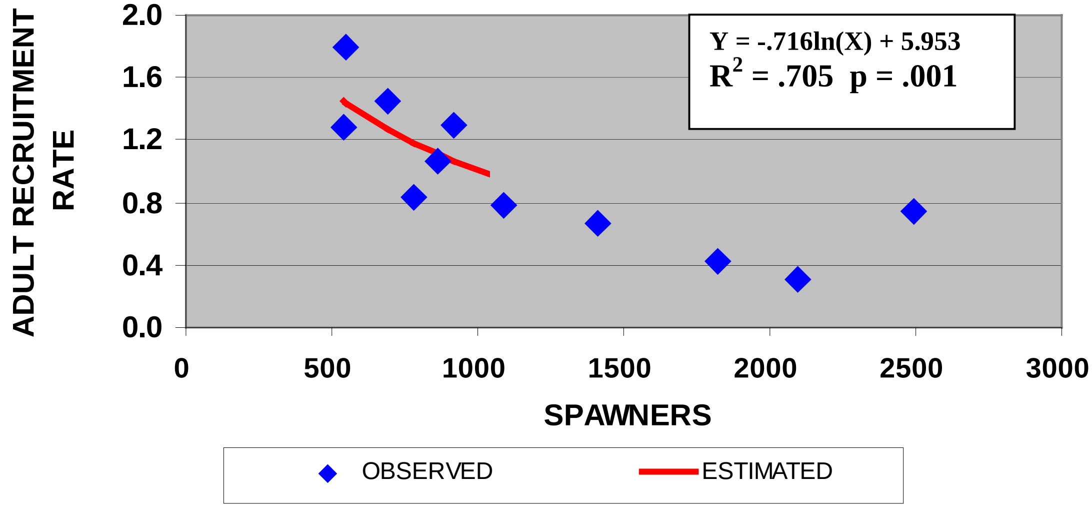


Figure 37. Yakima steelhead adult recruitment rate as a function of brood year spawning escapement

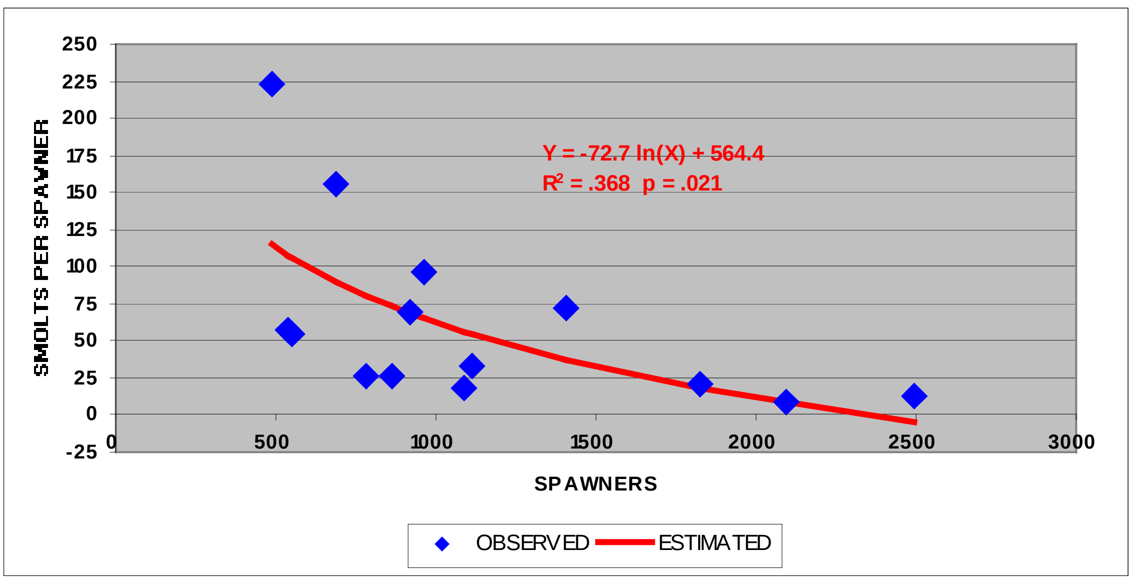


Figure 38. Yakima smolt productivity (smolts per spawner) as a function of brood year spawners

Coho

Stocks and Distribution

Although endemic coho were extirpated in the early 1980s, natural reproduction of hatchery-reared coho, out planted as smolts, is now occurring in both the Yakima and Naches Rivers (Figure 39). Natural reproduction is evident from the increasing occurrence of zero-aged coho parr in samples taken at numerous points in the basin (YN, unpublished data, 2000). Adult passage data at Roza Dam from 1941 - 1968 indicate that the endemic stock was early-run. The vast majority of the hatchery coho smolts out planted since 1985 have also been early run.

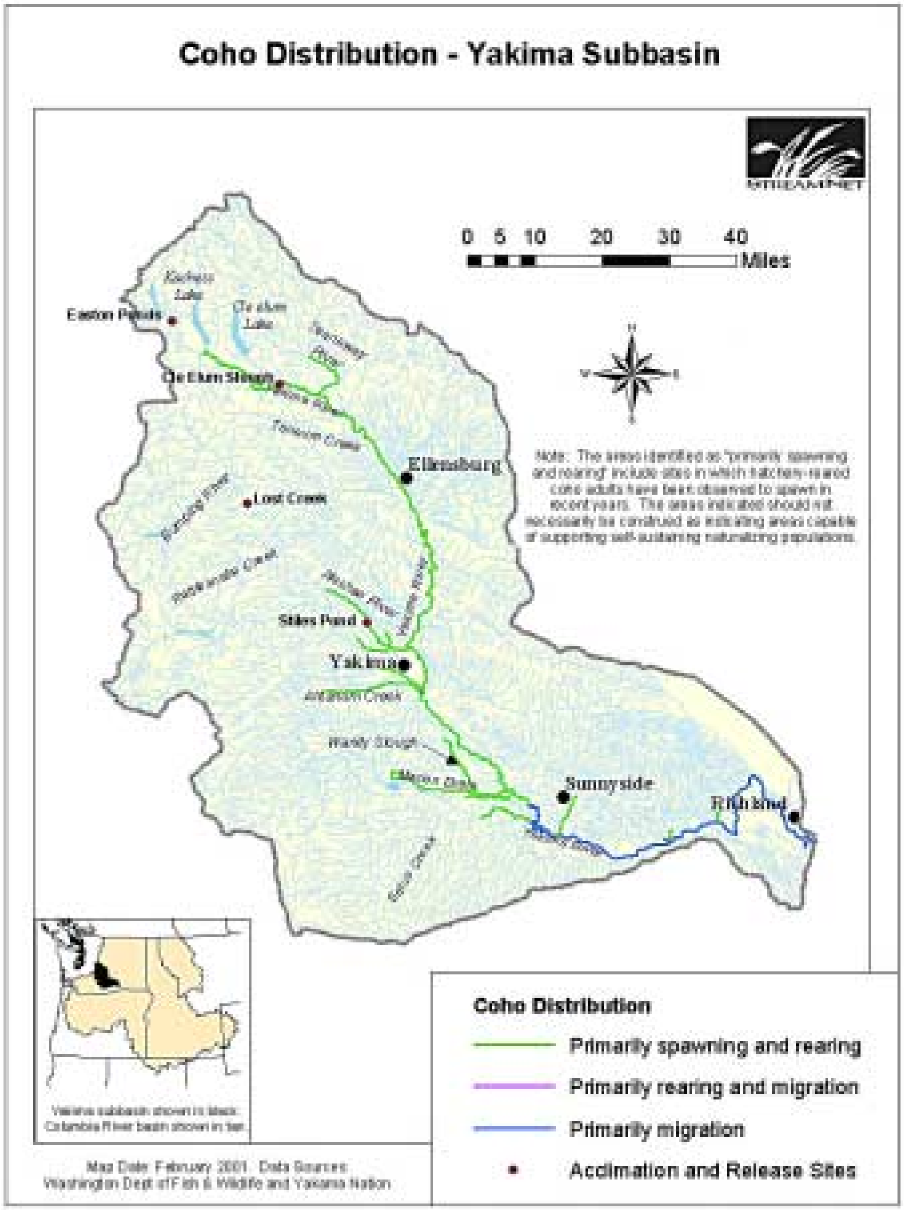


Figure 39. Coho distribution in the Yakima subbasin

Based on fragmentary WDFW records of spawner surveys, the endemic stock spawned in the upper Yakima above the Cle Elum confluence and in the Naches, primarily in the lower alluvial reaches, below the Tieton confluence. Bryant and Parkhurst (1950) report that coho also spawned in smaller tributaries of the upper Yakima, such as Taneum and Umtanum Creeks, in the early years of the 20th century, and affidavits from early settlers of the Wenatchee basin state that “silvers” were found in virtually every perennial creek and river in the basin before extensive development. It is now assumed that coho utilized virtually every low-gradient, perennial stream in the basin prior to extensive habitat alteration in the late 19th century (Yakima Subbasin Plan, 1990).

Efforts to restore coho within the Yakima basin rely largely upon releases of hatchery coho. The Yakama Nation has released between 85,000 and 1.4 million coho smolts in the Yakima Basin annually since 1985. However, before 1995, the primary purpose of these releases was harvest augmentation; after 1995, the primary purpose became a test of the feasibility of re-establishing natural production.

The current, naturalized run spawns in reaches downstream of the historical areas because, until 1999, the vast majority of hatchery smolts were acclimated and/or released well downstream of historical spawning areas. As was evident from the monitoring of radio tagged adult coho in the fall of 1999, most coho now spawn in proximity to their acclimation and release points, primarily in the middle Yakima below Sunnyside Dam (from RM 95 - RM 104; Dunnigan, 2000). In recent years, coho spawning has been documented in side channels of the mainstem Yakima between Roza Dam and the town of Wapato (~RM 100) and in the Yakima Canyon (RM 129 – RM 146); in Naches River below the Tieton confluence; and in numerous smaller tributaries including Corral Cr., Spring/Snipes Cr., Toppenish Cr., Marion Drain, Wanity Slough, Ahtanum Cr., Wide Hollow Cr., Cowiche Cr., and Buckskin Slough.

Kreeger and McNeil (1993) and (Yakama Subbasin Plan, 1990) estimate the historical coho run at 44,000 and 150,000, respectively. Coho returns since regular outplanting began in 1985 have increased steadily, climbing from 0 in 1984 to a peak of 5,700 in 2000 (Figure 40). Few of the outplanted coho were marked until the current brood year. Therefore the proportion of natural origin recruits in recent returns is unknown.

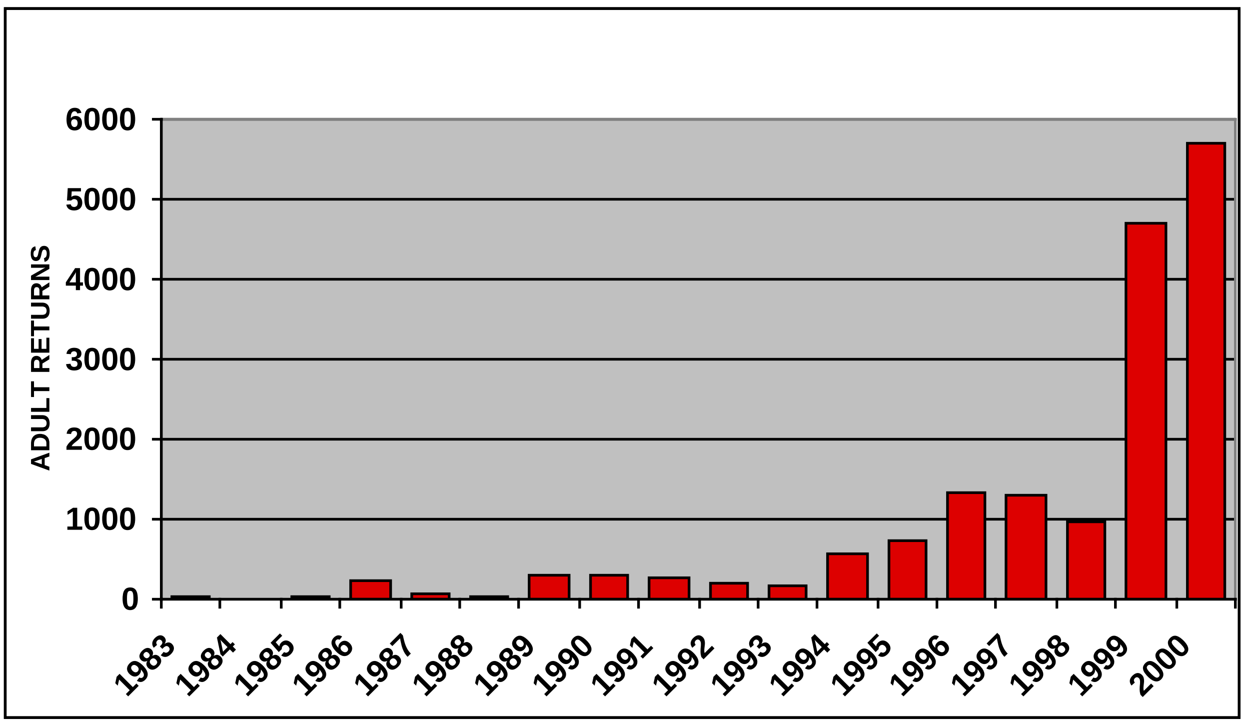


Figure 40. Returns of coho salmon adults and jacks at Prosser Dam, 1983-2000

The spawning distribution and spawning success of coho returning to the Yakima is just beginning to be determined. Earlier attempts to determine the spatial distribution of spawning coho in the Yakima compromised by difficulty in finding redds. A measure of the problem is the fact the ratio of adults passing Prosser Dam to redds counted later in the season during the period 1989 – 1996 was approximately 25:1. Thus, assuming a 50% sex ratio, only about 8% of the potential redds were discovered (YN 1997).

A preliminary reproductive success experiment conducted in Wenas Creek in 1998 showed that most female hatchery coho construct redds (Dunnigan 1999). This study also intended to determine egg-to-fry survival for these first generation hatchery fish by capping the redds and collecting and counting the fry as they emerged. High water, unfortunately, prematurely terminated the study.

A three-year radio telemetry study was initiated in 1999 to determine the spawning distribution of coho in the Yakima basin. The first year of this study produced the following findings. Most coho homed back to the general vicinity of the three lowest acclimation sites from which coho smolts were released in the spring of 1998.

Sockeye

Before unladdered irrigation dams were built at the outlets of all four natural sockeye rearing lakes over the period 1904 - 1910, the sockeye run was probably larger than any other in the Yakima Basin in terms of numerical abundance. (Yakama Subbasin Plan, 1990). Historically, juvenile sockeye reared in all of the headwaters lakes—Keechelus, Kachess, Cle Elum and Bumping—and adults probably spawned both in the lakes and in feeder tributaries. Historic sockeye run size prior to the construction of seven mainstem Yakima dams has been estimated as 211,104 fish (TRP, 1999).

Except for a handful of fish returning from experimental releases of hatchery-reared, Wenatchee stock sockeye smolts in the years 1992-1995, and a number of experimental releases of sockeye smolts in the 1940’s, sockeye have not returned to the Yakima basin since the1920’s.

Pacific Lamprey

Pacific lamprey are currently recognized as a category 2 candidate species as listed by the U.S. Fish and Wildlife Service. Pacific lamprey are declining in most, if not all, areas of the Columbia Basin (Close et al. 1995). Historically, Native Americans fished for lamprey in the Yakima basin, which suggests that they were quite abundant (Hunn, 1990). Currently, lamprey are not harvested in the Yakima River because of their scarcity. Although fish counting facilities at Prosser and Roza dams are not equipped properly for counting adult lamprey, some have been observed during the past few years. Five adult Pacific lamprey have been observed on video tapes between 1992 and 1996 at Prosser Dam and one at Roza Dam (Joel Hubble, YN, personal communication). In 1995, five adults were collected, and in 1996 one adult was collected at the Chandler Juvenile Fish Facility (Mark Johnston, YN, personal communication). Furthermore, the following number of juvenile lamprey (western brook or Pacific lamprey) were collected at the Chandler Juvenile Fish Facility between 1993 and 1996: 1993 - 613; 1994 - 102; 1995 - 367; 1996 - 27 (Mark Johnston, YN, personal communication).

The Causes of Anadromous Fish Decline

The decline of salmon and steelhead in the Yakima Basin occurred in two major phases. The first phase, covering the years 1850 through roughly 1900, saw Yakima runs decline approximately 90% from historical values (Davidson 1953; Tuck 1995; Lichatowich 1996). In the second phase, covering the years 1900 to the present, native sockeye, coho and summer chinook were extirpated and the abundance of the other stocks fell to small fractions of historical values. The major cause of decline in the catastrophic first phase was clearly diversion of instream flows for irrigation (Tuck 1995; Lichatowich 1996), although overharvest in early mainstem fisheries also played a role in the extirpation of summer chinook.

In his thesis on the impacts of irrigation development on anadromous fish in the Yakima Basin, Tuck (1995) documents significant irrigation withdrawals beginning in the 1870's and a dramatic acceleration after the railroad reached Yakima in 1884. By the mid-1890's, most smaller tributaries were "completely appropriated" (*viz.*, were dried up by late spring) by a host of unscreened irrigation diversions. Tuck also documents the "complete appropriation" of the mainstem Yakima itself by 1905. Tuck (1995) and Lichatowich (1996) point out that withdrawal rates over the entire complex of diversions exceeded 90% throughout the period of smolt outmigration. No provision to exclude smolts from any of these early irrigation ditches was made. Indeed, except for one small diversion on the Naches River, which was screened in 1928, *none* of the hundreds of diversions in the Yakima Basin were screened until the Public Works Administration program of 1934 – 1940 (Tuck, 1995). Therefore, the probability that a smolt would survive from the upper Yakima to the Columbia was extremely small, and the bulk of the phase 1 decline can be attributed primarily to smolt entrainment in irrigation diversions. Factors such as mainstem and ocean harvest, Columbia hydroelectric projects and widespread alteration of the floodplain and channel of the Yakima River itself would become dominant only later.

Two other impacts associated with the operation of irrigation diversions in the relatively recent historical past deserve special mention. Although both impacts have now been significantly reduced or eliminated, they played an important role in determining the status of existing runs. These impacts are the passage problems associated with Roza Dam from its completion in 1940 until a new ladder was installed in 1989, and the complete dewatering of extensive reaches below Cle Elum Dam on the Cle Elum River, Wapatox Dam on the lower Naches, and Sunnyside and Prosser Dams on the lower Yakima.

The structure and operation scheme of Roza Dam and its fish ladder has had a devastating effect on upper Yakima coho and steelhead. Until a new facility was installed in 1989[7], the ladder at Roza Dam was dewatered whenever the pool was lowered, as it routinely was at the end of the irrigation season. From 1941 through 1958, the pool was lowered, on average, from October 19 through March 17 (data from the BOR Yakima Project Office's online HYDROMET system). Therefore, based on coho and steelhead passage timing at Roza, the fish ladder was dewatered and the upper Yakima was inaccessible to roughly 70% of the coho run and virtually all of the steelhead run. A power-plant was added to Roza Canal in 1959, providing an economic incentive to keep water flowing through the canal (and the ladder) during as much of the year as possible. After installation of the power plant, the canal and ladder remained flowing continuously except during periods of severe icing, essentially restoring full access to the upper Yakima to steelhead. From 1959 until 1989, however, access still would have been denied to about 30% of a coho return with an early run-timing. Full access for both species was essentially restored when the new ladder was completed in 1989.

Tuck (1995) documents many episodes of vast fish kills when outlets from reservoirs were shut off or irrigation diversions diverted the entire streamflow, and miles of the Cle

[7] The new ladder passes fish whether the pool is up or down.

Elum, lower Yakima and lower Naches Rivers were dried up. Most of these episodes occurred in the 1930s and 1940s, although dewatering below Sunnyside and Prosser Dams occurred as recently as 1977.

Resident Fish

Bull Trout *(Salvelinus confluentus)*

In the past, wild bull trout *(Salvelinus confluentus)* occurred throughout the Yakima River subbasin. Today, however, they are now fractured into isolated stocks. Although bull trout were probably never as abundant as other salmonids in the Yakima basin, they were certainly more abundant and more widely distributed than they are today (WDFW 1998). In June 1998, the U.S. Fish and Wildlife Service listed bull trout in the Columbia River basin as threatened under the Endangered Species Act. Historical and present distribution of Yakima basin bull trout is indicated in Table 25.

Currently, nine bull trout stocks have been identified in the basin. Distinct stocks are present in the Yakima River, Ahtanum Creek, Naches River, Rimrock Lake, Bumping Lake, North Fork Teanaway River, Cle Elum/Waptus Lakes, Kachess Lake, and Keechelus Lake (WDFW 1998). All nine bull trout stocks in the Yakima basin are native fish sustained by wild production, as there are no hatchery bull trout stocks in Washington state. According to WDFW, there is no information to indicate that these are genetically distinct stocks; they are treated separately because of the geographical, physical and thermal isolation of the spawning populations. See Table 24 for summary of annual redd counts of these nine bull trout stocks.

Three bull trout life history forms are present in the Yakima basin: adfluvial, fluvial and resident. Adfluvial stocks occur in Rimrock, Bumping, Kachess, Keechelus and Cle Elum/Waptus lakes (WDFW 1998). Adfluvial stocks spawn and, in the early stage, rear in streams, with most growth and maturation occurring in lakes or reservoirs. Adults enter mainstem rivers early in summer, often holding near their natal tributaries for months before migrating upstream. Most mature adults range in size between 20 and 32 inches.

A fluvial stock is present in the mainstem Yakima River; a resident stock occurs in Ahtanum Creek; and fluvial/resident forms are present in the Naches River drainage and in the North Fork Teanaway drainage (WDFW 1998). Fluvial bull trout spawn and, in the early stage, rear in smaller tributaries with major growth and maturation occurring in mainstem rivers. They may move randomly throughout river systems, generally congregating near spawning tributaries in the summer. Mature adults are usually smaller than anadromous or adfluvial char, ranging from 16 to 26 inches long. Resident bull trout spend all life stages (spawning, rearing, growth, maturation) in small headwater streams, often upstream of impassable barriers. Mature adults can vary from 8 to 15 inches, but they are seldom larger than 12 inches in total length. Resident native char have been observed to mix and interbreed with migratory forms unless physically separated by barriers.

It is possible that anadromous forms also occurred in the Yakima basin in the past (WDFW 1998). Run timing of the Keechelus Lake stock and the spawning population in the South Fork Tieton River (part of the Rimrock Lake stock) are distinct. Run timing for other Yakima stocks is not distinct from other Washington state bull trout or is unknown (WDFW 1998).

Table 24. Annual summary of bull trout spawning surveys in the Yakima subbasin, 1984-2000

STREAM INDEX	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
YAKIMA RIVER (F)																	
Keechelus to Easton Reach	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2*
AHTANUM CREEK (R)																	
N.F. Ahtanum Cr. (Shellneck Cr.)	–	–	–	–	–	–	–	–	–	9	14	6	5	7	5	7	11
M.F. Ahtanum Cr.	–	–	–	–	–	–	–	–	–	–	–	–	1*	1*	–	0*	10*
S.F. Ahtanum Cr.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5*
NACHES RIVER (F)																	
Rattlesnake Cr. (Little Wildcat Cr.)	–	–	–	–	–	–	2	2*	–	–	4*	26*	38	46	53	44	45
American R. (Union Cr., Kettle Cr.)	–	–	–	–	–	–	–	–	–	–	–	–	25	24	31	30	44
Crow Cr.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	19	26
RIMROCK LAKE (AD)																	
S.F. Tieton R. (Bear Cr.)	–	–	–	–	–	–	32*	–	–	38*	167	95	233	177	142	161	144
Indian Cr.	29*	69*	16*	35*	25	39	69	123	142	140	179	201	193	193	212	205	226
BUMPING LAKE (AD)																	
Deep Cr.	–	–	–	–	–	17*	15*	84	78	45	12	101	46	126	98	107	147
N.F. TEANAWAY R. (F/R)																	
NF Teanaway/DeRoux Cr.	–	–	–	–	–	–	–	–	–	–	–	–	2*	0*	0*	–	0*
KACHESS LAKE (AD)																	
Box Canyon Cr.	5	4	3	0	0	0	5	9	5	4	11	4	8	10	16	17	10
Kachess R (upper)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0*	–	15
KEECHELUS LAKE (AD)																	
Gold Cr.	2	2	21	15	12	3	11	16	14	11	16	13	51	31	36	40	19
CLE ELUM LAKE (AD)																	
Cle Elum R. (upper)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7*

R = Resident, F = Fluvial, F/R = Fluvial/Resident, AD = Adfluvial
(Number of redds in index areas)

Table 25. Historical and present distribution of bull trout in the Yakima subbasin

R=Resident, F=Fluvial, F/R=Fluvial/Resident, AD=Adfluvial (Updated and modified from Goetz 1989)

Lake or Stream	Last Year Present	Last Year Checked
Yakima River (Benton Co) (F)	1997 (1)	2000
Yakima River (Yakima Co)(F)	2000	2000
Satus Cr.	1953	1991
Ahtanum Creek(R)	2000	2000
N.F. Ahtanum Cr.	2000	2000
Shellneck Cr.	2000	2000
M.F. Ahtanum Cr.	2000	2000
S.F. Ahtanum Cr.	2000	2000
Naches River(F)	2000	2000
Cowiche Cr.	1974	1981
Tieton R.	2000	2000
Oak Cr.	1999	1999
Rattlesnake Cr.	2000	2000
N.F. Rattlesnake Cr.	1996	1996
Hindoo Cr.	1995	1996
Dog Cr.	1996	1996
Little Wildcat Cr.	2000	2000
Milk Cr.	1996	1996
Bumping R. (Lower)	1997	1997
American R.	2000	2000
Kettle Cr.	2000	2000
Timber Cr.	1993	1993
Union Cr.	2000	2000
Little Naches R.	1998	1998
Crow Cr.	2000	2000
Quartz Cr.	1998	1998
Pileup Cr.	1998	1998
Rimrock Lake (AD)	2000	2000
S.F. Tieton R.	2000	2000
Short and Dirty Cr.	1994	1994
Spruce Cr.	1996	1996
Grey Cr.	1994	1994
Bear Cr.	2000	2000
Indian Cr.	2000	1997
N.F. Tieton R. (Lower)	1997	1994
Clear Lk.	1993	1996
N.F. Tieton R.(Up.)	1996	1990
Dog Lk.	1950 (2)	
Bumping Lake (AD)	2000	2000
Deep Cr.	2000	2000
Bumping River (Upper)	1994	1994

Lake or Stream	Last Year Present	Last Year Checked
Yakima River (Kittitas Co.)(F)	2000	2000
Coleman Cr.	1970	1984
Swauk Cr.	1993	1999
Easton Lake	2000	2000
N.F. Teanaway R.(F/R)	2000	2000
Jack Cr.	1997	1997
Jungle Cr.	1997	1997
DeRoux Cr.	2000	2000
Cle Elum Lake (AD)	1993	1993
Cle Elum R. (Upper)	2000	2000
Waptus Lake	1997	1998
Kachess Lake (AD)	2000	2000
Box Canyon Cr.	2000	2000
Kachess R. (Upper)	2000	2000
Mineral Cr.	2000	2000
Keechelus Lake (AD)	2000	2000
Rocky Run Cr.	1983	1983
Gold Cr.	2000	2000

(1) A single fish captured near Benton City by WDFW biologists (extreme rare occurrence).
(2) This record possibly species misidentification (brook trout).

According to WDFW, of the nine stocks identified, only Rimrock Lake is healthy; Bumping Lake is depressed; Yakima River, Ahtanum Creek, North Fork Teanaway, Kachess Lake and Keechelus Lake are critical and Naches and Cle Elum/Waptus Lakes are unknown (WDFW, SaSI Bull Trout/Dolly Varden Appendix 1998). Additional data are needed to determine the status of the unknown stock.

There are only a few historical references (mostly old catch records) that indicate the presence of bull trout in Yakima River tributaries. In all streams where bull trout are noted in the historical catch records relatively few fish were recorded compared to other game fish. Whether this is a reflection of historically low population abundance is difficult to tell.

Until information is collected to determine otherwise, all bull trout in the upper Yakima River mainstem will be considered as one stock with a fluvial life history pattern (WDFW 1998). An exception is the North Fork Teanaway River, which is considered a separate isolated resident stock (see North Fork Teanaway stock report). For now, the Yakima fluvial stock is assumed to be composed of fish that inhabit the mainstem between Roza Dam and the upper reservoir dams (i.e., Cle Elum, Kachess and Keechelus dams). Although the genetic characteristics of the stock have not been determined, bull trout in the mainstem of the Yakima River are considered distinct from other Yakima subbasin stocks based on physical, geographical and thermal isolating factors (dams, warm water temperatures, irrigation diversions, etc.).

Bull trout are strongly influenced by temperature and are seldom found in streams exceeding summer temperatures of 18º C. Cool water temperatures during early life history results in higher egg survival rates, and faster growth rates in fry and possibly juveniles as well (Pratt 1992).

All life history stages of native char are associated with complex forms of cover, including large woody debris, under cut banks, boulders, and pools. Preferred spawning habitat consists of low gradient streams with loose, clean gravel and water temperatures of 5 to 9º C in late summer and early fall. Depending on the life history form, rearing and over wintering habitat vary but still require cool clean water with insects, macro-zooplankton, and small fish for larger adults.

Slow juvenile growth delays maturation until about age five, and reproduction may only occur on alternate years. Native char may live for 12 or more years, reaching sizes over 20 pounds where adequate forage is available. Stock densities of native char are generally much lower than other native game fish such as cutthroat trout *(Oncorhynchus clarki)* and rainbow trout *(O. mykiss)*, or mountain whitefish *(Prosopium williamsoni)*. The migratory forms of native char may travel long distances to reach spawning tributaries. Mature native char normally penetrate farther upstream than any other salmonids present in the watershed.

Cutthroat Trout *(Oncorhynchus clarki lewisi)*

Cutthroat trout are plentiful in most high elevation headwater streams and present mainstem rivers in the Yakima subbasin upriver from the City of Yakima. Cutthroats are also present in Ahtanum and Toppenish Creek watersheds. Although little is known of historical distribution prior to the mid-1930's, the Bureau of Fisheries, now National Marine Fisheries Service, documented cutthroat presence in a number of tributaries during 1934-1942 stream habitat surveys (McIntosh et al. 1995). It is uncertain if westslope cutthroat are indigenous to the Yakima subbasin. Westslope cutthroat, originating from the WDFW egg taking facility at Twin Lakes, Chelan County (established in 1915) have been stocked into Yakima subbasin lakes for many years. In addition to westslope cutthroat, Yellowstone cutthroat (*oncorhynchus clarki bouvieri*) imported under the name "Montana black spot" have been stocked in the Yakima subbasin. Yellowstone cutthroat exist as hybrids with westslope cutthroat in Shovel Lake, Kittitas County.

Westslope cutthroat are not indigenous to the Yakima River basin according to Benke (1992), United States Department of Interior (1999) and Williams (2000), although Benke and Williams report that we cannot be certain of that conclusion. Trotter et al. (1999) reported that there discovery of pure "A-populations"(no hybrids and no stocking history) in Cabin and S. F. Toppenish Creeks lend weight to suggest that *lewisi* are native to the Yakima subbasin.

Determining westslope cutthroat distribution in Washington State is made difficult by the early, undocumented culture and outplanting of this subspecies. The first trout hatchery in Washington began operation with the culture of westslope cutthroat trout in the Stehekin River (Lake Chelan) in 1903(Crawford, 1979). Immediately, the translocation of *lewisi* to waters throughout Washington began. Not until 1931 did Washington Department of Game (which merged with the Department of Fisheries to become today's Department of Fish and Wildlife (WDFW)) begin recording stocking information. The Department of Game continued extensive use of *lewisi*, and by mid-century the bulk of available waters had been stocked. Westslope cutthroat continue to be stocked in Yakima basin alpine lakes to this day.

Apart from Lake Chelan and the Pend Oreille River where an abundance of relatively large cutthroat commanded the attention of pioneers, cutthroat trout in streams were obscured by their headwater location and small body size and upstaging by a variety of larger salmonids. Accordingly, the ethnohistorical record is mostly silent on the presence or absence of cutthroat. The picture is further blurred by the early scattering of cutthroat from the first trout hatchery in Washington (Stehekin River Hatchery, 1903) by entities dissolved decades ago along with their planting records. The undocumented translocation of cutthroats by interested non-professionals starting with pioneers is another confusing factor that challenges determination of historical distribution.

Regardless of their origin, westslope cutthroat are widely distributed throughout the Yakima subbasin. Though some Yakima subbasin streams were stocked directly, many cutthroat populations in streams were recruited from breeding populations in lakes. In Eastern Washington the number of streams and stream miles supporting *lewisi* has risen from 101 streams and 321 stream miles historically, to 493 streams and 1,509 stream miles, increases of 488% and 470% (Williams, 2000). Williams (2000) wrote:

> "There is no compelling evidence at this time to indicate that the westslope cutthroat trout is native to the Yakima watershed. Suitable habitat was accessible to invading cutthroat, as shown by the successful invasion of bull trout. Today's profuse abundance and widespread distribution of westslope cutthroat is a function of widespread stocking."

According to Williams, the lower Yakima (which corresponds to Washington Resource Inventory Area (WRIA) 37, the largest of three WRIAs in the Yakima subbasin) supports the least amount of westslope cutthroat trout water because suitable habitat is limited in the foothills area. In the lower Yakima, hatchery-origin *lewisi* spawn in eleven streams totaling 35.6 linear miles. The Naches watershed (WRIA 38) drains higher topography with more cutthroat trout habitat. Reproducing cutthroat inhabit 78 streams (235.7 stream miles) and 6 lakes (31.3 acres). Average elevation is highest in the upper Yakima (WRIA 39); cutthroat trout are most abundant here with 98 streams (258 miles) and 28 lakes (509.7 acres) of habitat supporting reproducing populations.

Cutthroat trout streams on tribal lands are not included in Williams report. His conservative methods likely underestimate the actual distribution of westslope cutthroat trout in the Yakima subbasin. Unsurveyed streams may have been identified as supporting cutthroat if: (1) the stream has been stocked (2) an alpine lake with a known self-sustaining population is present in the watershed (3) the stream reach is 3,000 feet or higher in elevation (4) an unsurveyed tributary is connected to a stream with a known reproducing population (5) anecdotal information indicates cutthroat are present. In addition, William did not have recent (after 1997) stream survey data from WDFW and other agencies that have recently conducted survey work within the Yakima subbasin.

The westslope cutthroat was petitioned in1997 for potential listing under the U. S. Endangered Species Act. The U. S. Fish and Wildlife Service determined that westslope cutthroat do not warrant listing (April 14, 2000, http://www.r6.fws.gov/pressrel/00-12.htm) WDFW had not completed a detailed status report for westslope cutthroat in the Yakima basin. Williams (2000) reports the status of westslope cutthroat in Washington "is healthy and safe, and listing them as threatened has no plausible foundation or utility."

Rainbow Trout (*Oncorhynchus mykiss*)

Many consider *O. mykiss* to have the greatest diversity of life history of any Pacific salmonid species (Shapovalov and Taft 1954, Barnhart 1986). The inland and coastal groups are genetically distinct and are separated in the Columbia basin in the vicinity of the Cascade Crest. These genetic groups apply to both anadromous and nonanadromous forms of *O. mykiss*. Rainbow (redband) trout east of the Cascades are genetically more similar to steelhead from east of the Cascades than they are to rainbow trout west of the Cascades. Rainbow trout that inhabit the mainstem of the upper Yakima basin provide the best naturally produced stream trout fishery in the state of Washington (Krause 1991; Probosco, 1994). In addition to the mainstem upper Yakima River, rainbow trout also inhabit most of the lower reaches of the Yakima's tributaries and the Naches River and lower reaches of its tributaries. Resident rainbow are also present in Ahtanum Creek and tributaries, and the Satus and Toppenish Creek watersheds.

In the Yakima subbasin, there is considerable variation in the growth and size of fish in different geographic locales. This variation may be influenced by ecological and genetic factors. Researchers attempted to determine some of the factors that are related to rainbow trout growth and length in 12 tributaries and seven sections of the mainstem of the upper Yakima River. Length-at-age of fish was determined from rainbow trout scales using the Dahl-Lea back calculation method. Preliminary results suggested that rainbow trout length-at-age is related to both ecological and genetic factors. The relative position of principal component scores of length-at-age data corresponded closely to the genetic stock structure dendogram of rainbow trout in the upper Yakima River basin. Length-at-age was negatively correlated with elevation. Furthermore, the length-at-age of trout in the tributaries was significantly less than in the mainstem of the Yakima River. Most trout spawning in tributaries were age 1+ and 2+, whereas in the mainstem-river, most spawning trout were age 2+ and 3+. The minimum size of sexually mature rainbow trout was negatively correlated with elevation. Researchers were unable to confirm repeat spawning based on scale analysis. During their first year of life, growth of rainbow trout in the mainstem of the Yakima River appeared to be low compared to the growth of rainbow trout in other large rivers of the Northwest. Slow first year growth supports the hypothesis that the young of year life stage is the one limiting rainbow trout production in the mainstem of the Yakima River.

To enhance the fishery in the mainstem of the upper Yakima River, a catch and release regulation was instituted in 1990. Average densities of rainbow trout in index sites in the reach between Roza Dam and the Cle Elum River confluence exceeded 250/km between 1991 and 2000 except for three years. Biology of resident rainbow in the upper mainstem Yakima River can be found in (Mongillo and Faulconer 1980; Campton and Johnston 1985; Fuller, 1990; Hindman et al. 1991, McMichael et al. 1992, Pearsons et al. 1993, Pearsons et al. 1994, Murdoch 1995; Hockersmith et al. 1996, Pearsons et al. 1996, Pearsons et al. 1998, Pearsons et al. 1999, McMichael et al. 1997, McMichael et al. 1998, McMichael et al. 1999, McMichael et al. 1999).

Rainbow trout in tributaries are an important recreational resources during the summer. Tributaries that are used frequently are Wilson Creek, Taneum Creek, Swauk Creek, Manastash Creek, and the three forks of the Teanaway River. Rainbow trout are distributed throughout most tributaries of the upper Yakima basin excluding some high elevation portions (Pearsons et al. 1996). Densities of rainbow trout in tributaries ranged from 16 to nearly 2000 trout/km and are generally highest in Taneum and Swauk creeks (Pearsons et al. 1996.). Biology of resident rainbow in tributaries to the upper Yakima River can be found in (Mongillo and Faulconer 1980; Campton and Johnston 1985; Hindman et al. al. 1996, Pearsons et al. 1996, Ham and Pearsons, 2000).

Although resident rainbow trout and anadromous steelhead trout have unique life histories, they spawn at similar times and similar geographic locations in the upper Yakima basin. Furthermore, it appears that the two forms utilize similar spawning habitat. Electrofishing, trapping, radio telemetry, redd surveys, and snorkeling methods were used to determine the spatial and temporal distribution of *O. mykiss* spawning (Pearsons et al. 1994, Pearsons et al. 1996, Pearsons et al. 1998). In addition, researchers documented many instances of interbreeding between rainbow and steelhead trout (Pearsons et al. 1998). Genetic evidence, using starch gel electrophoresis, as well as ecological evidence, indicated that rainbow trout and steelhead interbreed. Rainbow trout were genetically indistinguishable from sympatric steelhead collected in the North Fork of the Teanaway River (Pearsons et al. 1998). In addition, estimates of hatchery and wild fish admixtures in naturally produced *O. mykiss* indicated that hatchery rainbow trout had previously spawned with steelhead; and hatchery steelhead had previously spawned with rainbow trout (Pearsons et al. 1998). Researchers speculate that the magnitude of gene flow between rainbow and steelhead trout may vary spatially and temporally, depending in part, on the number of anadromous steelhead that spawn within an area or year and the number of steelhead offspring that rear and mature entirely within freshwater (Pearsons et al. 1998). Researchers' work suggests that aboriginal rainbow trout should be included within a steelhead ESU because the two forms are not reproductively isolated when in sympatry (Pearsons et al. 1998).

Wildlife

A large variety of wildlife species are associated with the Yakima subbasin because of the subbasin's diverse vegetative and geologic features. Big game animals found in the subbasin include black bear, black-tailed deer, mule deer, Rocky Mountain elk, bighorn sheep, mountain goats and cougar. Passerine birds, raptors, waterfowl and uplands birds are found in various habitats across the subbasin. Some bird species are year-round residents, while others are migratory. Large and small mammals inhabit the various habitats. In recent years, wolverines sightings have been reported in the upper portions of the subbasin, as have unconfirmed sightings of gray wolves. Federal- and state-listed threatened and endangered species exist in the subbasin (Tables 26 and 27).

Table 26. State-listed species in the Yakima subbasin

STATE ENDANGERED		STATE THREATENED		STATE SENSITIVE	
MAMMALS		**MAMMALS**		**BIRD**	
Gray Wolf	FE	Western Gray Squirrel	FSC	Common Loon	-
Grizzly Bear	FT	Lynx	FT	**AMPHIBIAN**	
Fisher	FSC	**BIRDS**		Larch Mountain Salamander	FSC
BIRDS		Bald Eagle	FT		
American White Pelican	-	Ferruginous Hawk	FSC		
Peregrine Falcon	FSC	Sage Grouse	FSC		
Sandhill Crane	-				
Snowy Plover	FT				
Upland Sandpiper	-				
Spotted Owl	FT				
REPTILES					
Western Pond Turtle	FSC				
AMPHIBIANS					
Northern Leopard Frog	-				
INSECTS					
Mardon Skipper	FC				

*Species may also hold a federal designation, such as Federal Endangered (FE), Threatened (FT), Proposed Threatened (FPT), Candidate (FC), or Species of Concern (FSC).

Wetland and Riparian Associated

Amphibians

Amphibians are important components in many ecosystems as both aquatic and terrestrial species, and in some systems comprise a major component of vertebrate biomass. For instance, tailed frog tadpoles constitute 90% of herbivore biomass in some small streams (Hawkins et al. 1988). Their predators include fish species such as cutthroat trout (Daugherty and Sheldon 1982). Additionally, amphibians can serve the function of biological indicators of ecosystem health (Blaustein et al. 1995). For example, tailed frogs may be particularly valuable as independent indicators of habitat quality for fish as well as amphibians, as they have the lowest thermal tolerance of North American frogs (Washington State Gap Analysis: http://salmo.cqs.washington.edu/~wagap/herps), and are very sensitive to sedimentation.

Little is known of the distribution, abundance and life histories of amphibians in the Yakima subbasin. Species associated with western Washington may occur in the northwestern portions of the subbasin (i.e., Northwestern salamander, Pacific giant salamander, red-legged frog.

Table 27. State candidate species for listing in the Yakima subbasin*

BIRDS		MAMMALS	
Northern Goshawk	FSC	Merriam's Shrew	
Golden Eagle	-	Townsends's Big-eared Bat	FSC
Merlin	-	Keen's Myotis Bat	
Yellow-billed Cuckoo	FSC	White-tailed Jackrabbit	
Flammulated Owl	-	Black-tailed Jackrabbit	
-urrowing Owl	FSC	Gray-tailed Vole	
Vaux's Swift	-	Brush Prairie Pocket Gopher	
Lewis Woodpecker	-	Western Pocket Gopher	FSC
White-headed Woodpecker	-	Wolverine	FSC
-lack-backed Woodpecker	-		
Pileated Woodpecker	-	**AMPHIBIANS**	
Loggerhead Shrike	FSC	Western Toad	**FSC**
Streaked Horned Lark	FSC	Columbia Spotted Frog	FSC
Purple Martin	-		
Slender-billed White-breasted Nuthatch	FSC	**BUTTERFLIES**	
Sage Thrasher	-	Silver-bordered Fritillary	-
Oregon Vesper Sparrow	FSC		
Sage Sparrow	-		
REPTILES			
Sharp-tailed Snake	-		
California Mountain Kingsnake	-		
Striped Whipsnake	-		

*Species may also hold a federal designation, such as Federal Endangered (FE), Threatened (FT), Proposed Threatened (FPT), Candidate (FC), or Species of Concern (FSC).

Northern Leopard Frog *(Rana pipiens)*

Predation by bullfrogs is thought to be a limiting factor (Leonard et al 1993). Waterfowl, fish, aquatic insects and snakes also prey on leopard frogs. Extensive mortality occurs on roadways, especially those built between breeding ponds and other water bodies used by these frogs. Agricultural chemicals and Rotenone kill tadpoles. Land use changes, development and irrigation projects contribute to declines of leopard frogs as well (McAllister et al 1999).

Columbia Spotted Frog *(Rana luteiventris)*

Factors leading to the decline in spotted frogs across the region are not fully understood, nor are the limiting factors for this subbasin. However, the loss and degradation of wetland habitats and the introduction of bullfrogs (*Rana catasbeiana*) are thought to be major factors (Leonard et al. 1993). Habitat fragmentation, long-term overgrazing, and alterations to aquatic systems, such as diversions for irrigation and development around springs also negatively impact spotted frogs (Nordstrom and Milner 1997).

Western Pond Turtle (*Clemmys marmorata)*

The western pond turtle is listed by Washington as an endangered species. It has been extirpated from most of its range in Washington. Fossil evidence from the Pleistocene era has been found in south-central Washington, suggesting that this species' range once extended into the Yakima subbasin. Construction of dams along the river and alteration of historic patterns of waterflow may have eliminated many suitable habitats within the last 70 years (Hays et al 1999). A recovery plan for western pond turtles is currently being implemented by WDFW (Hays et al 1999).

Tailed Frog *(Ascaphus truei)*

Within the subbasin, tailed frogs are found along permanent, fast-flowing streams of the Cascades. These frogs are quite sensitive to increases in water temperature and sedimentation of streams caused by logging and roading practices (Nussbaum et al 1983, Leonard et al 1993).

Construction of dams along the river and alteration of historic patterns of waterflow may have eliminated many suitable habitats within the last 70 years (Hays et al 1999). A recovery plan for western pond turtles is currently being implemented by WDFW (Hays et al 1999)

Western Toad *(Bufo boreas)*

Western toads utilize terrestrial and wetland habitats, but require wetlands for breeding. Toads are found in the western portions of the subbasin. Localized declines have been noted by Leonard et al (1993). This species is a candidate for listing in the state of Washington.

Waterfowl

Prior to irrigation development, the floodplain areas of the lower Yakima Subbasin were composed of diverse wetlands, river channels, riparian areas and grasslands (Oliver 1983). These diverse habitat complexes created by natural hydrologic processes supported abundant populations of breeding and wintering waterfowl. Presently the lower Yakima Subbasin still maintains healthy numbers of waterfowl.

Historically, the lower Yakima Subbasin, especially Toppenish Creek and the Yakima River from Granger to Mabton, contained a large portion of the Columbia Basin's wintering ducks and geese (Oliver 1983). These wintering populations began to decline in the mid-1970s (Figure 41). Once totaling between 250,000 and 300,000; wintering waterfowl numbers now average 30,000 to 40,000. This decline has been attributed to a population shift from the lower Yakima Subbasin to the Lower Columbia River (Lloyd et al 1983). Factors such as increased surface water due to hydroelectric development on the Lower Columbia River, changes in cropland patterns, and improved refuge conditions have contributed to this population shift (Thompson et al 1988).

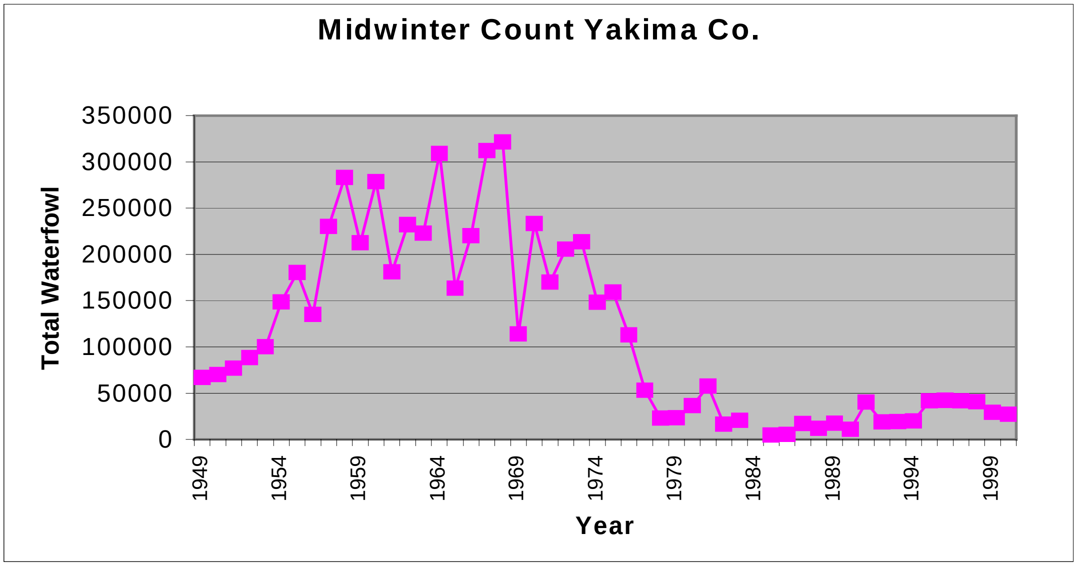


Figure 41. Midwinter count inYakima County

Mallards make up the majority of the wintering waterfowl found in the area. Pintails and green-winged teal are common in lesser numbers. Northern breeding populations of Canada geese generally move into the subbasin in early January of each year. Here numbers can reach as high as 40,000. They stay until mid-April before returning to their breeding grounds in northern Alaska. White-fronted geese make up a small component of the wintering goose populations. Groups of as many as 400 may be present in the spring. Tundra swans seem to be on the increase. As many as 250 can be seen in late winter and early spring of each year. Trumpeter swans are sighted as well, but in much smaller numbers.

The lower Yakima Subbasin has been recognized for its highly productive breeding habitats for many years (Oliver 1983). The most productive areas within the Subbasin have been, and continue to be, located on the Yakama Nation Reservation (Lockhart 1953). Though waterfowl production numbers have declined in many other areas of the Columbia Basin, the production in the irrigated portion of the lower Yakima Subbasin has remained relatively stable, if not slightly increasing since surveys began in 1955 (Figure 42). Larsen (1999) reported some of the highest mallard nest success rates in the country in idle fields within the Wapato Irrigation Project on the Yakama Nation Reservation. Brood survival, Larsen (1999) noted, was highest in wetlands associated with floodplains along Toppenish Creek.

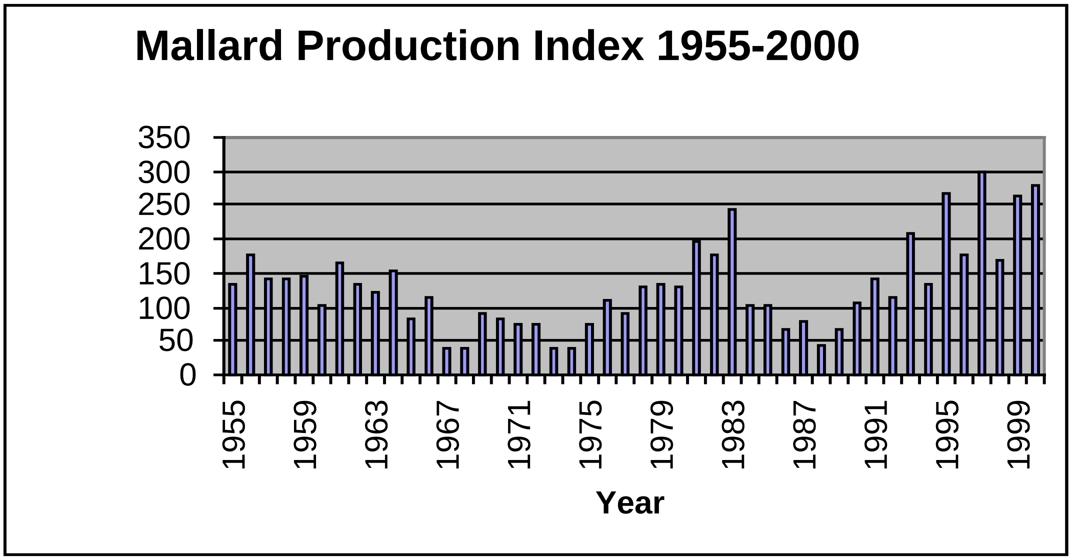


Figure 42. Mallard production index 1955-2000

Mallards are the most abundant breeders in the Yakima Subbasin. Dense wood duck numbers occur in the riparian gallery forests of the mainstem Yakima River from Selah Gap to Mabton. This area is responsible for most of the wood duck production in eastern Washington (Parker 1989). Other breeding species include gadwall, cinnamon teal, blue-winged teal, shoveler, redhead, ruddy duck, pintail, green-winged teal, ring-necked duck, and occasionally canvasback. Mountain streams support breeding populations of harlequin ducks and common mergansers, but the extent of these populations has not been adequately surveyed. Canada geese production has steadily increased since the 1950s. These birds are now common breeders in the riparian cottonwood forests of the mainstem Yakima River. Historic accounts of breeding swans exist, but no production is presently known.

Bald Eagle (Haliaeetus leucocephalus)

The bald eagle is listed as a state and federal "threatened" species in Washington. However, bald eagle populations are recovering toward target levels established by the Pacific States Bald Eagle Recovery Plan (U.S. Fish and Wildlife Service 1986). Bald eagles are found along marine shorelines and the shorelines of freshwater lakes and rivers. Eagles defend breeding territories to protect their preferred feeding sites and their nest, perch and roost trees (Stalmaster 1987). In Washington, breeding territories include upland woodlands and lowland riparian stands with a mature conifer or hardwood component (Grubb 1976, Garrett et al. 1993, Watson and Pierce 1998). Territory size and configuration are influenced by a variety of factors, including breeding density (Gerrard and Bortolotti 1988) and the types of foraging habitat and prey that are available (Watson and Pierce 1998).

Factors limiting bald eagles include:

- Human disturbance closer than 300 m at nesting sites
- loss of nesting sites to human activities such as logging or home site development
- Presence of communal roost sites in mature trees adjacent to feeding sites
- Adequate food sources, (such as spawning salmon)
- Impacts to key habitats from activities such as dredging, herbicide or pesticide applications, oil spills, toxic substances, or introduction of exotic species (WDW 1991)

Wintering eagles may roost communally, with 3 or more eagles perching consecutive nights in the same trees. Communal roosting probably enhances food finding on nearby foraging areas (Knight and Knight 1984). Eagles may gather in staging trees located between feeding grounds and roost trees prior to entering the night roost (Hansen et al. 1980, Anthony et at. 1982, Stalmaster 1987). The Yakima was identified as a significant bald eagle wintering area in southern Washington (Ichisaka 1989). One primary communal roost was identified in 1994 along the Yakima River; downstream from Ellensburg near the mouth of the Yakima canyon. Currently occupied nesting territories are limited in number in the Yakima Subbasin. They are known to occur at Rimrock Lake along the Yakima River near Toppenish Creek and at Lake Cle Elum.

Peregrine falcon *(Falco peregrinus)*

Peregrine falcons are listed by the state of Washington as endangered. Peregrines nest on the ledges of steep cliffs, usually along a river, lake or coastline. These birds feed on shorebirds, ducks and songbirds. Peregrines are periodically sighted during the winter (Audubon Christmas Bird count data) and are known to nest in the region. In 1987-89 the WDFW assisted the Peregrine Fund in a hacking project that helped reestablish breeding birds. Today, known eyries (broods) occur in at least 3 locations in the subbasin, with others likely undiscovered. Peregrines were recently down listed on the federal endangered species list from endangered to threatened based upon population recovery nationwide. Conservation needs still exist for protection of nesting sites and prey concentrations for this species.

Sandhill Crane *(Grus canadensis)*

The sandhill crane is a Washington state endangered species. During the mid-late 1990's, one pair of sandhill cranes nested in the southwest of the subbasin, on the Yakama Indian Reservation, but fledging has never been confirmed. Within 1 mile of the southwestern boundary of the subbasin, a second pair of cranes has nested and fledged young since the mid 1990s,

Cranes, in groups of 30-40 have been seen during migration in the Yakima Valley. Historically, cranes nested in the Yakima Valley, such as in the Ft. Simcoe area, when wetlands and wet meadows were more abundant (Bettinger and Milner 2000, http://www.wa.gov/wdfw/hab/phs/vol4/sndhlcrn.htm). A recovery plan for sandhill cranes in Washington is currently being created by WDFW.

Riparian Migratory Songbirds

A great number of neotropical bird species are associated with or require riparian habitats in the Yakima River subbasin. Many of these species (e.g., willow flycatcher, yellow warbler, yellow-breasted chat, red-eyed vireo, Vaux's swift) continually exhibit declining population trends in this region. Lewis's woodpeckers are closely associated with large cottonwood stands. Historically they were common in the cottonwood habitats of the Yakima basin but declines were noted after 1965, and they are now considered extirpated from the Columbia River riparian habitat. Wetland obligates include the Virginia rail, sora rail and marsh wren. Loss of riparian and riparian-marsh habitat for these birds resulted from agricultural conversion, drainage and alteration of habitats in the Yakima River subbasin and in the mainstem of the Columbia River. Many of these species are known to be in decline, likely due to habitat loss at both ends their migratory existence, and are of great conservation concern (Audubon Blue List 2000).

Forest Associated

Canada Lynx *(Lynx canadensis)*

The Canada lynx was recently listed as threatened under the Endangered Species Act and as threatened by the state. Lynx occupy large areas of boreal, sub-boreal, and montane forests, and once occupied a range extending from Alaska across Canada and into portions of the northwestern United States, Great Lakes region and upper New England (Ruediger et el. 1999). Over-harvesting and direct and indirect effects of habitat alteration have led to drastic population declines and range reduction. In Washington, most recent occupancy has been documented in the extreme north, although recent detections on the Gifford Pinchot National Forest indicate a south-central Washington Cascades population may still exist. Within the Yakima subbasin, most potential lynx habitat lies at higher elevations on federal, tribal or state land. Extensive surveys have not been conducted, but recent furbearer camera and hair station work have failed to indicate presence of lynx in the sub basin. Extensive suitable habitat, however, is present, and lynx presence is likely.

Wolverine *(Gulo gulo)*

Wolverines are a candidate for listing in the state of Washington. These animals are quite rare in Washington and sightings in this state are thought to be animals dispersing from Canada (Banci 1994). Although occasional sightings are reported in this subbasin, no confirmed sightings exist (Jeff Bernatowicz, pers. comm.2000). Large, sparsely inhabited forest wilderness areas with adequate year-round food supplies (carrion) provide habitat for wolverines (Kelsall 1981). Wolverines are scavengers, cleaning up after other carnivores such as bears, wolves and cougars. The loss of wolves and grizzly bears in the subbasin likely affected the availability of food for wolverines. Additionally, the loss of salmon runs due to hydroelectric development has possibly reduced locally productive wolverine populations in North America (Banci 1994).

Gray Wolf *(Canis lupus)*

Gray wolves are listed as Endangered by the state of Washington and the US Fish and Wildlife Service. Gray wolves have been documented in the North Cascades of Washington. The 1997 Washington Gap Analysis project identifies areas of Kittitas County, in the northwestern portion of the subbasin, as being in core habitats for wolves (ftp://198.187.3.50/pub/gapdata/mammals/gifs/calu.gif). Documented sightings of gray wolves exist in the Yakima subbasin, but it is unclear whether those sightings are of dog/wolf hybrids or dispersing wolves. There are no documented wolf packs in the Yakima subbasin. Wolves require large expanses of contiguous habitat and an adequate prey base (primarily deer). Wolf populations were reduced primarily through predator control efforts.

Grizzly Bear (*Ursus arctos*)

Grizzlies are a Washington state Endangered species and US Fish and Wildlife Service Threatened species. No confirmed sightings of grizzlies exist in the Yakima subbasin, although a confirmed sighting exists immediately west of the subbasin. Grizzly bears are known to occur in the North Cascades of Washington. However, resident grizzly bears have not been confirmed in Washington south of the North Cascades. Given the expansive home ranges of grizzly bears, it is feasible that dispersing bears may pass through the western portions of the subbasin. Grizzly bear populations were reduced primarily through predator control efforts.

Black Bear (Ursus americanus)

Black bears have very large home ranges and use a variety of habitats throughout the year, but are primarily associated with forested habitats. However, during the fall (prior to hibernation), high densities of bears can be found in fringe/transition habitats because of the availability and diversity of food sources found in oak and riparian stands of this important habitat zone. Black bear populations are thought to be slowly increasing in the state of WA (WDFW 2000) but their status within the subbasin is unknown.

Fisher *(Martes pennanti)*

Fisher are listed in the state of Washington as endangered. Historically, fisher were present in the subbasin, but are believed extirpated at this time. Although occasional sightings are reported each year, no confirmed sightings have been documented in recent times (Jeff Bernatowicz, pers. comm. 2000). Fisher occur in late-successional coniferous and mixed conifer/ deciduous forests but at low abundances. Trapping, predator control and habitat loss/ alteration, in combination with low population densities and reproductive rates, have led to the near extirpation of fisher in Washington (Lewis and Stinson 1998).

Flammulated Owl *(Otus flammeolus)*

The flammulated owl is a migratory, cavity nesting, insectivorous owl, feeding primarily on moths and orthopterans (Johnson 1963, Goggans 1986). They are thought to be closely associated with old ponderosa pine forests, where presence of nest cavities in large diameter snags and insect prey provide optimum habitat (Bull and Anderson 1978, Reynolds et al. in Reynolds and Linkhart 1987). They are known to nest primarily in cavities of trees at least 12" in diameter (Jones and Stokes, 1980, Thomas et al. 1979). On the Yakama Indian Reservation, owl surveys have indicated highest abundance of this species in the ponderosa pine zone of the reservation (Gina King, Yakama Indian Nation, pers. Comm.).

Ponderosa pine habitats in the Yakima sub-basin occur on the lower and south facing slopes and plateaus of the eastern Cascades. These stands have been intensively logged for their high value timber. As a result, most of the large diameter, dry forest ponderosa pine is gone.

Flammulated owls are a candidate species for listing in Washington State (WDFW), based upon historic and continued loss of old pine forests to timber harvest. Population status and trend for flammulated owls in Washington are largely unknown. Research is needed on population status and trends, and habitat use in Washington.

Northern Goshawk *(Accipiter gentiles)*

The goshawk is a fierce forest hawk that preys upon a variety of small mammals and birds in the forest environment. It is likely that goshawks occur in all forested regions of Washington). Goshawks generally nest in closed canopy, coniferous forests throughout Washington and they are most often found in mature and late-successional forests (WDFW Goshawk report, 1999). Goshawks forage in forested and non-forested habitats in winter, and are sometimes observed during winter in the lower elevations of the Yakima subbasin, (Stepniewski 1999) suggesting a down-slope migration. The WDFW led a study of goshawk biology in the upper subbasin in 1994-95. They are listed as a state candidate species, and are identified as "special emphasis species" in the Plum Creek Habitat Conservation Plan, which includes much of the upper Yakima sub basin. Density studies of breeding pairs in Washington are needed, giving an estimate of territory spacing in varied habitat as and a reasonable estimate of population (WDFW Goshawk report, 1999). Conservation issues with goshawks revolve particularly around protection of adequate habitat in nesting territories.

Northern Spotted Owl *(Strix occidentalis caurina)*

The northern spotted owl is a medium sized forest owl that resides primarily in mature, forest habitats in the Pacific Northwest (Forsman et al. 1984). They occur at highest abundance in mid-elevation mixed conifer forests in the Yakima sub basin, where there remains a high proportion of unfragmented habitat. They seldom occur in forests dominated by ponderosa pine. Their main prey item is the Northern flying squirrel in the Yakima subbasin (Bevis et al. 1997). They are federally listed as "threatened" and are listed by Washington state as "endangered." A 1993 analysis of demographic data collected across the range of this subspecies indicated that spotted owl populations are in significant decline in the northwest, and that the rate of decline appeared to be accelerating (Burnham et al. 1996). The most recent analysis included five additional years' data, and indicated that the population continued to decline at 3.9% per year (Franklin et al. 1999). Logging of mature, closed forest habitats has been the main factor in this owl's decline in the Northwest.

In recent years the closely related barred owl (*Strix varia*) has expanded its range into the Pacific Northwest, including the Yakima subbasin (Yakama Nation, unpub. data, Sovern, USFS pers. comm.). Competition with this more aggressive *Strix* species has become a factor of unknown magnitude in the decline of spotted owls.

Within the Yakima subbasin, most spotted owl sites occur on federal lands on the Wenatchee National Forest, with additional sites occurring on tribal, state and private lands. Plum Creek Timber Company and the Washington state Department of Natural Resources (DNR) have approved Habitat Conservation Plans (HCPs) with the US Fish and Wildlife Service that allow for continued harvest of some owl habitat, while maintaining habitat on a few sites (Plum Creek 1996, WA DNR 1997). Long-term research and monitoring by USFS Pacific Northwest Research Laboratory, the National Council of the timber industry for Air and Soil Improvement (NCASI) and the Yakama Nation is ongoing in the sub basin. This work is planned to continue in the Cle Elum area until at least 2004, and will continue for an unspecified time on the Yakama Reservation. This research is beginning to indicate similar declines in owl populations here as in other regions (Sovern, USFS pers. comm.). The Wenatchee National Forest and Yakama Indian Reservation populations appear to be declining at a rate comparable to the range-wide average.

Issues surrounding spotted owls revolve primarily around protection of mature forest habitats from timber harvest. Continued monitoring of populations is necessary to assess the success or failure of conservation efforts for this species.

Migratory Songbirds

Songbirds occur in the Yakima sub-basin in great abundance and variety, based upon the rich diversity of habitats that occur there. Migratory and resident species occur in all available habitats, with riparian and forest zones particularly species rich (Stepniewski 1999). Many neo-tropical migrants are of particular concern, as their numbers are believed to be declining continent wide (Ehrlich et al. 1988).

Sharptail Snake (C*ontia tenius*)

This species is a candidate for listing by the state of Washington. Its distribution is spotty, but is known to occur in northern Yakima Co. and central Kittitas Co. within this subbasin. Sharptail snakes are associated with the edges of coniferous or open hardwood forests and can be found in moist decaying logs or talus slopes (Nussbaum et al 1983, Storm and Leonard 1995). Sharptail snakes feed almost exclusively on slug and they are found only in locations and times that slugs are present (Storm and Leonard 1995). Little else is known about the sharptails in the subbasin.

Cavity Excavators

Because of the diversity of habitats in the Yakima subbasin, a diversity of woodpeckers can be found breeding here. Cavity excavators are excellent indicators of dead wood habitats, especially large diameter snags, because these habitats are critical for nesting. These cavity excavating species are very important because the cavities that they create are used by a wide variety of other animals as well.

Pileated Woodpeckers (*Dryocopus pileatus*)

Pileateds are a candidate for listing by the state of Washington and are uncommon/ rare and declining in the subbasin (Stepniewski 1991). These birds rely on mature and old growth forests with large amounts of dead wood. Pileateds feed primarily on insects such as beetles and carpenter ants and require large snags for nesting and roosting (WDW 1991).

White-headed Woodpeckers (*Picoides albolarvatus*)

White-headed woodpeckers are a candidate for listing by the state of Washington and are uncommon to very rare in the subbasin (Stepniewski 1999). This woodpecker species is dependent upon mature ponderosa pine forests for nesting and foraging (WDW 1991) and is declining, as this habitat type is lost (Marshall 1997).

Black-backed Woodpecker (*Picoides arcticus*)

These woodpeckers are rare in the subbasin and their distribution is spotty, depending on abundance of prey (beetles) (Stepniewski 1999). They are a candidate for listing by the state of Washington. They utilize mature and old growth lodgepole pine, ponderosa pine and mixed conifer stands, especially those that have been damaged by disease or fire (WDW 1991).

Passerines/Neotropical Migrants

Songbirds occur in the Yakima sub-basin in great abundance and variety, based upon the rich diversity of habitats that occur there. Migratory and resident species occur in all available habitats, with riparian and forest zones particularly species rich (Stepniewski 1999). Many neo-tropical migrants are of particular concern, as their numbers are believed to be declining continent wide (Ehrlich et al. 1988).

Shrub Steppe Associated

Ferruginous Hawk (*Buteo regalis*)

Ferruginous hawks exist in low number in shrub steppe and grassland regions of several eastern Washington counties. The state population is estimated at between 50 and 60 nesting pairs (Washington Department of Fish and Wildlife, 1996). The Yakima Subbasin contains portions of the North and Central Ferruginous hawk Recovery Zones, and portions of hawk areas 6) Yakima Training Center, 7) Rattlesnake Hills, and 10) Horse Heaven Hills (Washington Department of Fish and Wildlife, 1996). Isolated rock outcrops, and other platforms that provide unobstructed views are used as nest sites by these hawks. Their diet consists primarily of small to medium-sized mammals, such as pocket gophers, mice, and ground squirrels, but often includes birds, reptiles, and insects. Persecution by early settlers reduced the number of ferruginous hawks in the West. Recent pressures are frequently related t land-use practices. Conversion of shrub-steppe for agriculture or grazing has broadened the influence of human activity, reduced nesting opportunities, and lowered the diversity and abundance of prey species.

Burrowing Owl *(Speotyto cunicularia)*

Once widespread across grasslands and shrub steppe of North America, the burrowing owl is declining throughout much of its range in the Western States and Canada (Sheffield 1997). Burrowing owls depend on burrows excavated by other animals such as marmots, ground squirrels, and badgers. Agriculture and other land conversion has reduced available habitat by eliminating burrows used by these owls, and also by eliminating habitat for mammals that create burrows.

Golden Eagle *(Aquila chrysaetos)*

This large and impressive raptor occurs in the Yakima subbasin, with a breeding concentrations occurring in the Yakima sub basin along the Tieton River and in the Yakima Canyon between Ellensburg and Yakima (J. Bernatowicz, WDFW, pers. Comm) Golden eagles require large, open areas for feeding. Nests generally are located on cliffs or in large trees (Anderson and Bruce 1980, Snow 1973). Hares, rabbits, ground squirrels and marmots are the most important prey for golden eagles (Snow 1973, McGahan 1967).

This eagle is a creature primarily of open country, nesting in cliffs and large trees. Their prey are primarily small mammals, particularly rabbits, hares and ground squirrels. Populations are threatened by habitat loss, human disturbance, loss of prey species from habitat modification and incidental poisoning in association with predator control projects. They are listed in Washington as a state candidate species (WDFW 1991). Conservation issues revolve around protection of nest sites and adequate prey populations in healthy shrub steppe environments.

Sage grouse *(Centrocercus urophasianus)*

Sage grouse were historically found in shrub steppe habitats throughout eastern Washington. The current population in Washington is estimated to be about 1000, with approximately 300 of these birds is found in the Yakima Subbasin in Yakima and Kittitas counties. The remaining 700 birds reside in a contiguous subpopulation in Douglas and Grant counties. The two subpopulations are separated by about 50 km; the barrier between the 2 populations is dominated by irrigated agriculture in western Grant County. Sage grouse populations in Washington declined 78% between 1960 and 2000. Their populations are continuing to decline in Washington due to long-term effects of habitat conversion, degradation, and fragmentation, and population isolation (Hays et al. 1998, Schroeder et al. 2000).

Migratory Songbirds

Sage thrasher, loggerhead shrike, sage sparrow, and Brewer’s sparrow are neotropical migrants that appear to be closely associated with shrub steppe habitats (Vander Haegen et al. 1999). Populations of several shrub steppe-associated songbirds, including the Brewer’s sparrow and loggerhead shrike, are declining (Saab and Rich 1997). Fragmentation and degradation of shrub steppe adversely affect some species, although relatively few have been studied. Sage sparrows are less abundant in fragmented landscapes; Brewer’s sparrows and sage thrashers occur commonly in habitat fragments and are more abundant in areas with good quality habitat (Vander Haegen et al. 2000). Fragmentation of shrub steppe leads to lower productivity in several species, including the Brewer’s sparrow and sage thrasher (WDFW, unpublished data). Sage sparrows are generally found only in blocks of shrub steppe greater than 1000 ha (2470 acres) (Vander Haegen et al. 2001).

Populations of species with small home ranges and limited dispersal capabilities are likely to become isolated and vulnerable to extirpation. Wildlife populations in fragmented habitats may be more vulnerable to predation. In Washington, Brewer’s sparrows, lark sparrows, and sage thrashers had greater nest predation rates in fragmented habitats than in continuous habitats (WDFW, unpublished data). Habitat-specific population parameters, including productivity, dispersal, and adult and juvenile survival are unknown for most of these species. Numerous species, including the sage sparrows and grasshopper sparrows, are not monitored adequately by the Breeding Bird Survey and will require specialized monitoring to detect and monitor changes in their populations (Saab and Rich 1997).

Pygmy Rabbits *(Brachylagus idahoensis)*

Currently no pygmy rabbits are known to occur with the Yakima Subbasin, although there are some remnant shrub steppe habitat blocks that may offer potential for future pygmy rabbit reintroduction. There are only 3 known populations of pygmy rabbits remaining in the state. The remaining populations appear to be isolated from each other and none appear to be large enough to survive without direct intervention (such as augmentation with pygmy rabbits from other states). Pygmy rabbits were historically associated with relatively deep soils within shrub steppe communities (Washington Department of Fish and Wildlife 1995). Because the deep soil habitats were preferred areas for conversion, most are now used for irrigated and dryland agriculture. The widespread loss and fragmentation of shrub steppe has resulted in dramatic declines in the statewide population (Musser and McCall 2000).

Black-tailed (*Lepus californicus*) and White-tailed (*Lepus townsendii*) Jackrabbits

Both species of jackrabbits are closely associated with shrub steppe habitats, and consequently, their populations have shown some of the same downward trends as other shrub steppe obligates. White-tailed jackrabbits tend to be more closely associated with the more mesic shrub steppe habitats, and black-tailed jackrabbits with the relatively arid and/or disturbed sites. Although population figures are not available, the long-term declines appear to be dramatic.

California Mountain Kingsnake (*Lampropeltis zonata*)

Kingsnakes are a candidate for listing by the state of Washington. Although the Washington population appears to be mostly restricted to Klickitat and Skamania counties, an occurrence of this species was noted in the southeastern portion of the subbasin by Nussbaum et al (1983) and Storm and Leonard (1995). Kingsnakes appear to be associated with rotting logs in pine and oak forests and chaparral (Storm and Leonard 1995). Little else is known about this species in the subbasin.

Striped Whipsnake *(Masticophis taeniatus)*

Striped whipsnakes are found in sagebrush, grasslands and dry rocky canyons and are known to occur in the eastern portions of the subbasin (Nussbaum et al 1983). Whipsnakes are a candidate for listing by the state of Washington. Little else is known about this species in the Yakima subbasin.

Other Shrub Steppe Dependent Species

Numerous other species including the sagebrush vole, sagebrush lizard, pigmy horned lizard, and striped whipsnake are largely restricted to shrub steppe habitat and populations of all appear to be declining. Unfortunately the population, behavior, and habitat information is insufficient to understand the long-term relationships between populations and declining quality and quantity of shrub-steppe.

Fringe/Transition

Elk *(Cervus elaphus)*

Elk were undoubtedly present in the shrub steppe habitats of eastern Washington prior to the arrival of settlers (McCorquodale 1985, Dixon and Lyman 1996, L. Lyman pers. comm., G. Cleveland pers. comm.). The current Yakima elk population developed from the reintroduction of 100 Rocky Mountain elk (*Cervus elaphus nelsoni*) from Yellowstone National Park in 1913 and 1915, which significantly contributed to any remnant animals in the area (Bryant and Maser 1982). These animals were released west of Yakima near Cleman Mountain and in the vicinity of Ellensburg (Houston 1982, Robbins et al. 1982, Morse 1988).

The Yakima Elk Herd is the largest of ten herds identified in Washington State. The Yakima herd is an important resource that provides significant recreational, aesthetic and economic benefit to the people. This herd ranges over 1,743 mi^2 between the Columbia River to the east and the Cascade crest to the west and Interstate 90 to the north and the Yakima Indian Reservation to the south. A management plan for the Yakima elk herd is currently being prepared by the WA Dept. of Fish and Wildlife.

Western Gray Squirrel *(Sciurus griseus)*

The western gray squirrel was listed as a state threatened species in Washington in 1993, when surveys indicated that the species' distribution was becoming increasingly patchy and disjunct. Small isolated populations remain in south Puget Sound, the Lake Chelan area, the southeast slope Cascade region and the Columbia River Gorge, the latter being the largest in the state. The exact reasons for this decline are unknown. However, changes in the landscape likely play a key role. Many years of fire suppression and selective logging practices have altered Washington's oak-conifer communities and the habitat of the western gray squirrel. On mesic sites, invading Douglas fir overtops the slow-growing, fire-adapted oak. In drier areas, drought and insects further stress overstocked forests. In some areas this has resulted in a wholesale loss of conifer, leading to intensive logging in remaining conifer stands. Dense pockets of conifer in oak woodlands, which frequently contain clusters of western gray squirrel nests, have been subjected to logging at an increasing rate in southwestern Washington.

Western gray squirrels historically occurred on the Oak Cr. Wildlife Area. Current records of gray squirrel nests exist for disjunct locations on the Yakama Indian Reservation. Within the Yakima subbasin, western gray squirrels historically occurred on the Oak Cr. Wildlife Area (WDW 1993). Current records of gray squirrel nests exist for disjunct locations on the Yakama Indian Reservation.

Lewis' woodpecker (*Melanerpes lewis*)

These woodpeckers have shown a recent decline in the western US and are a candidate for listing by the state of Washington. Although a few year-round colonies are known, this bird is primarily a summer resident in the subbasin (Stepniewski 1999). These birds utilize insects and acorns and thus their distribution in the subbasin is limited mainly to the transition zone between forested and shrub-steppe environments that contain open ponderosa pine stands and oak. However, they can also be found locally in riparian habitats that contain large diameter cottonwood snags or ponderosa pine. Breeding habitats are open pine/ oak stands that contain a brushy understory (WDW 1991).

Specialists

Mardon Skipper (*Polites mardon*)

The mardon skipper is a small butterfly that is listed by the state of Washington as endangered. It occurs in only four small and geographically disjunct locations in Washington, Oregon, and California. Only 9 of 18 historic sites in Washington are known to still be occupied. The Washington population of mardons is believed to consist of only a few hundred individuals in these 9 isolated locations.

Mardons are found in open, fescue grasslands within ponderosa pine savanna/woodlands. Size of the openings varies and can be as small as 1/2 acre. Elevations at which mardons have been found in the southern Cascades range from 1,900 to 5,100 feet. Sites with mardons have ranged from meadows associated with wetlands/ riparian areas to dry, open ridge tops. Idaho and red fescues are important for egg laying and feeding by larvae (Potter et al. 1999). Mardon skippers were found near the southwestern border of the Yakima subbasin during surveys conducted in 2000.

Silver-bordered Bog Fritillary (*Boloria selene atrocostalis*)

The silver-bordered bog fritillary is an extremely colonial butterfly with disjunct populations. This butterfly is strongly associated with boggy meadows and true bogs, with northern bog violet (*Viola nephrophylla*) as a key host plant (Pyle 1974, 1990). This butterfly's dependence on specific wetlands or wetland types makes it vulnerable to population declines (Larsen et al 1995). This butterfly is a candidate for listing in the state of Washington. The only known location of this butterfly in the Yakima subbasin is the Moxee bog.

The availability of boggy meadows and true bog habitat with adequate populations of violets restricts the distribution of the silver-bordered bog fritillary. Natural succession within these plant communities jeopardizes habitat components necessary for this butterfly. Human activities that alter the water table or reduce floristic diversity, such as land development, wetland drainage, intensive fertilizing and grazing, and pesticide application, also threaten this butterfly's existence (Larsen et al 1995).

Larch Mountain Salamander *(Plethodon larselli)*

This salamander is listed as a Washington state Sensitive species. Very little is known about this salamander and its range is quite limited (previously known from only 35 sites in Skamania Co., Lewis Co. and Klickitat Co.). Recently, this salamander has been found in the Yakima subbasin, thus extending its known range (D. Darda, Pers. Comm.). It is known to inhabit steep, moist talus slopes. These talus slopes typically have a dense overstory, thus keeping the talus cool and moist.

Activities that have negatively affected this species include the removal of rock from talus slopes for road building, degradation of microhabitat conditions from logging of overstory trees, and permanent loss of talus fields from human development (WDW 1993).

Bats

Bats are a very diverse group of mammals, with many species present in the Yakima sub basin. However, they have not been systemically surveyed there, and a complete species list does not exist. There are 15 species known to occur in Washington (Bats Conservation International, 2000), and based upon the diversity of habitats in this sub-basin, most of them are likely to occur there. Habitats utilized by bats for roosting and hibernating include dead trees, cliffs, caves and crevices in basalt cliffs. Conservation of bats is an ongoing concern with losses of species and habitats thought to be occurring continent wide. At least one winter colony of Townsend's big-eared bats, a federal Species of Concern, occurs on the Naches Ranger District of the Wenatchee National Forest in the Naches River drainage.

Very little is known about bat species diversity, abundance or basic habitat needs in the Yakima sub-basin. Surveys and research are needed in the sub-basin to better determine conservation needs for bats. Protection of identified critical habitat features is needed where such features are known, and new locations should be sought out for protection where they occur.

Bighorn Sheep (*Ovis Canadensis*)

Bighorn sheep are native to the Yakima sub basin, and were an important species to Native American people. They were eliminated by over hunting and disease transmitted from domestic animals by the early 1900s. Bighorn habitat consists primarily of grasslands or grass/shrub habitats adjacent to or intermixed with precipitous terrain characterized by rocky slopes, ridges and cliffs, or rugged canyons. This rugged terrain also serves as escape cover and lambing areas (Johnson 1983).

Reintroduction of Bighorn sheep by WDFW have re-established reproductive herds in 4 areas of the Yakima sub basin: Tieton River, Cleman Mt., Umtanum Creek, and Selah Butte (WDFW Game Status Rpt, 1999), and a limited number of recreational hunting permits for rams are issued for these herds each year. Reintroduction efforts began in the 1960s, and continue today in the Tieton herd, where animals were released in 1998 and 1999. 1999 population estimates for each area are Cleman Mt:,135; Tieton River, 25; Umtanum, 174; and Selah Butte, 47.

The Bighorn sheep population in the Yakima subbasin is healthy and growing. However, the history of Bighorn sheep here has been one of boom and bust. Historical declines have likely been associated with disease, particularly *Pastueurella H*., which is transmitted by domestic sheep. The probability of another disease outbreak is high (WDFW Game status report, 1999). Domestic sheep graze on ranges in the near vicinity of all of these populations.

Mountain Goats *(Oreamnos americanus)*

These animals live in the high alpine zone where steep slopes and strong winds keep the snow from accumulating and preventing feeding on forbs, sedges, grasses and low shrubs. They are not a true goat, but are related to the old world mountain antelopes. They have dense white fur, and both sexes carry sharp horns. The males use their horns to fight during breeding season (Leopold et al. 1981).

Mountain goat populations in Washington have been declining for many years. Historically there may have been as many as 10,000 animals, but today there are approximately 4,000. Hunting opportunities have decreased accordingly, and despite reductions in harvest, herds have continued to decline. In the Yakima sub basin, goats occur on all of the high, snowy mountains of the high Cascades. The Goat Rocks, Bumping River, Blazed Ridge and Chinook Pass are a few of these areas.

Population surveys in the Yakima subbasin, however, have proven to be difficult, and expensive, and therefore limited. Based on available information, this population appears to be stable, but decreased from historic levels, particularly in the northern portions of the subbasin (WDFW Game status Rpt 1999, Lee Stream, pers. Comm 2001.).

Beaver *(Castor canadensis)*

Beavers are semi-aquatic and require permanent, flowing water. Beavers feed on aspen, willows, cottonwoods, sedges and other riparian associated vegetation. Beavers are important in maintaining and enhancing riparian and aquatic ecosystems. Their activities, especially dam building, provide benefits such as sediment deposition, elevation of water tables, which in turn enhances riparian and wetland systems, reduction of stream velocity, enhancement of fish and wildlife habitats and flood protection (Olson and Hubert 1994).

Historically, trapping removed beavers from the subbasin, resulting in the alteration of their riparian/ wetland habitats. Various factors, including the poor placement, construction and maintenance of road systems in the subbasin, have contributed to changes in stream channel morphology. Stream channels have become incised, secondary channels have been lost, and beaver access to floodplains has been reduced. These factors contribute and relate to a decline in the recruitment of aspen and cottonwood, both food sources for beaver. Additionally, fire suppression, the lack of thinning, and livestock grazing have contributed to the loss and degradation of beaver habitat, especially in higher elevation, forested areas of the subbasin. Currently, beaver populations are more prevalent in lower elevation areas of the subbasin, than in forested, higher elevation areas.

Habitat Areas and Quality

Historic Overview

Yakima River Basin: Critical Elements in the Preservation, Recovery, and Maintenance of Ecological Integrity[8]

Normative is the functional norm which ensures that we provide the essential ecological conditions and processes necessary to maintain diverse and productive salmonid populations (Return to the River, 1996).

The long term genetic variability of anadromous fish is directly linked to the ecological variability expressed in the river basins they occupy (Montgomery, 2000). Given this relationship, it is critical for the survival of these and related species that the normative processes that create and maintain habitat structure and function be clearly identified and sustained (Independent Scientific Group 1999, 2000). In the Yakima River basin many of these processes have been altered or in some cases eliminated (Snyder and Stanford, 2000). For example, human-induced structural changes have reduced habitat diversity and significantly reduced the extent of habitat available on all large alluvial floodplains within the basin (Eitemiller et al., 2000). Additionally, the construction and operation of irrigation reservoirs eliminated all four glacial lakes as essential habitat components, eliminated habitat upstream of these reservoirs, and altered the seasonal hydrograph of all downstream reaches.

Knowing the details of human interactions and the physical processes that create and maintain biotic diversity is required in almost every management action regarding anadromous fish. Furthermore, it is essential that a detailed model of the historic habitat conditions for the Yakima River basin form a key part of the template from which measurements of change in habitat diversity are made. Significant progress towards understanding historic habitat conditions for the major alluvial floodplains in the basin has been made; this information is currently being used to prioritize land acquisitions and restoration efforts (Reaches Project, *In Progress*). Unfortunately, comparable mapping and data has not been assembled for other key essential landscape components that enable informed modeling, maintenance, and restoration efforts.

Examples include: canyon reaches, glacial valley reaches, glacial lakes and associated reaches, the mainstream meander belt, and historic conditions in tributary streams; all critical elements in the preservation, recovery, and maintenance of the basin's ecological integrity.

The Yakima River basin is comprised of three broad landscapes:

A. Glaciated: The Upper Yakima and Naches River Basins

[8] By Morris L. Uebelacker and Douglas J. Eitemiller

The present-day form of these landscapes was shaped by the cumulative processes of flowing ice and water over millions of years. It is within these high elevations that most of the basin's water is first captured, stored, and released. Climatic and other biophysical processes operating here therefore determine the character of all downstream reaches in both the normative and non-normative systems. The glacial valley bottoms are core areas of fluvial/hyporheic connectivity in this landscape. Deep accumulations of snow during winter and sudden rain-on-snow events typify the patterns and processes of water storage and movement critical to the ecological integrity of the entire river basin.

B. Ridge and Canyon: The Yakima Folds physiographic province is dominated by anticlinal ridges, synclinal valleys, and hydraulically cut canyons

Dominated by Columbia River flow basalts, this landscape is characterized by very arid conditions along its eastern margins.
The western margin is a complex interplay of Columbia River flow basalts, Cascade volcanics, tectonic processes, glacial out-wash and periglacial process, mass wasting, landslides, and hydraulic erosion. A substantial snow-pack accumulates above 2,500 feet in elevation during most winters throughout its western boundaries. It is a landscape of powerful winds, and therefore, subject to repeated snowfall/melt periods throughout late winter and early spring. Occasional yet intense thunderstorms can produce outburst-floods during late spring and summer. The product of mainstream rivers, hydraulically cut canyons are the dominant landforms found here, and link the valley basin landscapes from the delta through the headwater reaches. Tributaries also show substantial canyon development, and most contain smaller alluvial floodplains nested in the canyon bottoms (Gellenbeck, 1999). The headwater basins of tributary steams flowing through this complex landscape exhibit a low gradient development that capture, store, and release water slowly, and thereby contribute to controlling base flow (King, 1997). Water is stored in a substantial number of basin aquifers, and in countless small aquifers located in basalt interstices. Emerging springs and bands of moisture running along the same contour reveal their sub-surface location. These basalt aquifers control base flow in small perennial and intermittent stream segments throughout the Ridge and Canyon landscape. Stream flow patterns across this landscape are extremely variable, and numerous small-to-medium sized watersheds add critical habitat diversity (Sullivan, 1994).

C. Valley Basins: Primary structural basins containing deep alluvial fill and wide canyons with substantial alluvial development

Valley Basins are the zone of maximum ecological connectivity, and serve as a biophysical processor of upstream inputs and downstream outputs. Although imbedded within all three broad landscapes of the Yakima River basin, it is within the Valley Basin landscape that alluvial floodplain development becomes most evident. These large mainstream alluvial floodplains capture, store, and release most of the basin's water delivered by the Glacial, and Ridge and Canyon landscapes. Numerous tributary streams join the mainstream Yakima River here. These tributary/mainstream connections have developed alluvial fans, floodplains, and canyons as distinct habitat components. Each structural component plays a critical role in the functional biophysical processes that create high habitat biodiversity.

These broad landscapes are connected through the interaction of complex geologic, climatic, geomorphic, edaphic and biotic processes operating at multiple temporal and spatial scales. Ultimately, these interactive processes have prescribed the template for the diversity of life-history strategies exhibited by historic and contemporary populations of all organisms inhabiting each landscape. The high-energy human systems that now occupy this basin have altered the interactions of these processes at the place (site), landscape, and regional scales. In no part of the basin are these alterations more prominent than within the fluvial/hyporheic system. The river is the common connection between places and landscapes often separated by many miles, thousands of feet of elevation, and often, under very different biophysical controls. Understanding how the fluvial/hyporheic system has been altered and what efforts should be pursued to restore connectivity is predicated on an understanding of past structural and functional complexity. It is required that this knowledge be used when judging ongoing and future human activities.

Overview of Historic Alteration

In brief overview, the fluvial/hyporheic systems in the Yakima River basin were essentially normative at the signing of the Treaty of 1855 with the Yakama Nation. This assumption is made with the acknowledgement that thousands of horses were occupying the basin (Ross, 1855), and that beaver populations had been substantially reduced (Glauert and Kunz, 1972). The addition of horses to the ecology of the basin is known to have had localized affects on vegetation, and it is anticipated that in places this modification may have altered ecological dynamics (Uebelacker, 1984). Furthermore, the removal of almost all beaver by trappers no doubt modified the ground water-surface water interactions of most tributary streams, mainstream side channel habitats, and riparian biophysical succession. To date, the specifics of these alterations are for the most part undocumented at the place, landscape, and regional levels.

These modifications were closely followed by the introduction of cattle (1860), and then sheep (1880), (Sullivan, 2000). In combination with substantial numbers of horses, these two domesticates transformed the native shrub-steppe, forest, meadow, and riparian communities throughout the river basin. Transformations which ranged in elevation from the delta of the Yakima to the high cirque basins and ridges of the Cascade range induced structural changes in vegetation/edaphic interactions that led to increased soil erosion and compaction, stream siltation, and in many areas, initiated stream entrenchment. The severity of these problems was noted by early researchers and marks a major alteration of the fluvial/hyporheic system (Plummer, 1900; Cotton, 1904).

Settlement of the Yakima River basin by non-native people was sporadic and restricted to a few key locations before 1860. Immigration and settlement by Euroamericans was underway by 1880, and focused on water sources in the Valley Basin landscape (Tuck, 1995). By the middle 1880s, the effects of the Township and Range survey system and subsequent private land-use strategies were helping forge the new non-normative template. Settlement patterns were intimately linked to the perceived allotment of water within the basin, and restricted to lower elevations where temperature and moisture allowed for reasonable attempts at both dry-land and irrigated agriculture. Floodplain farming and private canal building that delivered water to lands above the floodplain are hallmarks of fluvial/hyporheic alterations during this period. Furthermore, timber harvests were focused on forest-edge and mainstream valleys, while domestic animal herders followed a pattern of transhumance (Plummer, 1900). Timber harvested along the mainstream Yakima and tributary streams was floated down to the newly emerging industrial centers in Yakima and Ellensburg at high water. These log drives where the first cultural practice directed at creating a single thread river across the floodplains, and mark a threshold in channel modification.

By the 1890s, the Northern Pacific Railroad had laid track and built bridges up the mainstream valleys of the Yakima River basin (Campbell et al., 1916). This single act cut-off and redirected alluvial floodplain process along all major floodplains of the mainstream, and established confined points of entry and blockages on tributary streams. The railroad gave focus to the emerging settlement and land-use patterns in the basin and connected human-induced modifications across a much wider region (Meinig, 1968). Unlike most roads at this time, the railroad severed critical linkages between processes that created and maintained biotic diversity in the basin, and set the stage for the growth of towns from the delta to the glacial valleys. This persistent structure was subsequently added to with trunk lines. Later, the Northern Pacific's route was mirrored on the opposite side of the river by the Milwaukee Railroad in the upper reaches of the basin (Kripner, 1996).

The growth of towns within the basin, and outside opportunistic commercial and industrial development, promoted capitalization of the landscape. This encouraged large, privately funded, irrigation efforts, and eventually led to federally subsidized projects of a monumental scale. In the early 1900s, the federal government joined in the full-scale industrial development of the Yakima River basin (Buckley, 1936; Tuck, 1995; Anderson, 1996). From the formation and management of the Forest Reserves to the construction of dams and irrigation canals, the fluvial/hyporheic systems were intentionally yet unknowingly altered. Continued domestic stock grazing had profound impacts not only on riparian systems, but also on public and private forests and rangelands (Cooperative Western Range Survey, 1936). This transformation was so complete that its signature has been indelibly imprinted on most forest and range plant communities. When combined with the effects of fire suppression, only vestiges of the endemic system remain. (Rummel, 1954).

Before World War II, transportation systems evolved from single-thread horse trails into wagon roads, and then to automobile routes (Uebelacker, 1980; Eitemiller et al., 1995). The emergence of a transportation landscape reflected utilization of the basin's water resources, and often followed the survey grid patterns across the Valley Basin landscape (USGS 15' Quadrangles, 1906-1956). Mimicking the irrigation features they serviced, road names like Lateral A and Marion Drain became commonplace on maps. When not following stream corridors, road systems in the more arid Ridge and Canyon landscape were often built across deep loess deposits and jagged rocky terrain. These early roads, and those that followed, had a profound impact on small tributary streams throughout the basin, further disconnecting floodplain processes and thereby increasing instability in hill slopes and exacerbating erosion along stream margins. City, county, and state roadways amplified the discontinuity of the fluvial/hyporheic system, and tethered future transportation structures to locations in direct conflict with the structure and function of fluvial systems.

Each of these human-induced alterations is cumulative, and therefore, sustains and multiplies the effects of the preceding activity. For example, the construction of federally funded flood irrigation systems, and the subsequent modification of the hydrograph that followed, expedited increased investment on all major floodplains within the Yakima River basin. This modified hydrograph initiated dike building by private citizens, counties, cities, and state and federal governments. Consequently, lateral confinement of the major alluvial floodplains increased. The building of dikes permitted more intensive settlement and investments on the "reclaimed" floodplains.

By the close of World War II, human systems operating within the Yakima River basin had developed an agricultural-based economy within the Valley Basin landscape. Five major dams located in the Glacial Valley landscape, and supported by thousands of miles of canals, roads, and dikes, are classic structural and functional alterations -serial discontinuities that alter the entire system from the high glacial valleys to the delta (Ward and Stanford, 1995a; 1995b). Agricultural-industrial cities and towns developed at major drainage and transportation junctures in direct relationship to the available and captured resources. Interstate freeways were expanded, often dissecting and laterally segmenting large alluvial floodplains, and adding a new element to floodplain ecology -gravel-pit ponds (Norman et al., 1998; Norman, 1998).

The Post World War II era marked the continued expansion of the agricultural economy and a rapid acceleration of timber harvesting. Timber extraction spread up the mainstream Yakima River and its major tributaries (Uebelacker, 1980; Eitemiller et al., 1995). Logging practices utilized the narrow draws of first, second, and third order streams as skidding pathways. Timber landing sites were often located at stream intersections, on alluvial fans, and tributary floodplains. Once these easily accessible stands were cut, harvest methods shifted to an elaborate skyline system that required

mid-slope roads and fostered almost complete removal of merchantable timber. Examples of these patterns are found in Cabin Creek of the Upper Yakima River basin, and are replicated in Rock Creek, Nile Creek and the Little Naches in the Naches River basin. The cumulative result of these rapidly evolved harvest technologies severely disconnected the fluvial/hyporheic system across the forested portions of the basin. These activities triggered increased sedimentation of streams, channel instability, and landslides (McIntosh et al., 1994), further disrupting the basin's normative process of capturing, storing, and delivering water (Stanford, 1998). Ironically, agricultural and Native American communities became locked in a heated legal and political battle over diminished flows in the river basin during this time (Tuck, 1995).

Today, only a few isolated river fragments within the drainage basin can be considered normative with respect to historic conditions (Figure ?? 2). It is with little wonder that anadromous fish and other species have diminished in abundance and distribution within the Yakima River basin, and therefore, should be clear that remaining habitat fragments with the potential to respond to normative processes are high priorities for acquisition, restoration, and enhancement. Ultimately, the connections between the various structural components that create and maintain habitat diversity must be restored across the landscapes of the Yakima basin to ensure genetic diversity and long-term species viability.

Floods are crucial to the creation and maintenance of habitat diversity, and therefore, genetic diversity in aquatic species. These natural disturbance regimes determine the structure and function of alluvial floodplains (Amoros et al., 1987; Ward and Stanford, 1995a), refresh canyon reaches, and reset meander belts; all key landscape components of the Yakima River basin. Without disturbance, floodplains, canyons, alluvial fans, and their associated hyporheic systems, become senescent and simplify. In the face of human structural intervention, flow regulation, and lateral confinement, large alluvial floodplains simplify to the point of being poorly functioning mimics of the ecology of canyon reaches.

Within the Yakima River basin this effect is most obvious in the Selah floodplain where railroads, highways, dikes, and gravel mining operations have led to the rapid simplification of a formerly diverse array of channel forms and associated wetlands. The Selah floodplain was once a premier Native American "usual and accustomed" fishery (Warren, 1959), and ranked among the highest landscape components with respect to biodiversity. Research has demonstrated that most of the major floodplain reaches have been reduced laterally by approximately 60 percent with a concurrent reduction in channel complexity (Eitemiller et al., 2000; Reaches Project, *In Progress*).

So interconnected is habitat heterogeneity on these floodplains that even the establishment, survival, and diversity of riparian vegetation is directly altered by flow reductions and lateral confinement. For example, cottonwood forests are in the latter stage of senescence along all of the Yakima's alluvial reaches. Cottonwood and associated willow stands have little chance of reproducing without floods that create necessary seedbeds on newly scoured surfaces. Equally important is the normative drop of river levels after floods, which enables new seedlings to maintain contact with the falling limb of the hydrograph (Braatne, Rood, and Heilman, 1996). Without these normative processes the floodplain's biophysical environment becomes simplified and is less productive. Ultimately, this translates to a reduction in the genetic diversity and viability of anadromous fish and other organisms connected to the river and its associated floodplains.

Cultural Ecology

Over the long run, cultural systems will only maintain those assemblages of environmental components that afford a selective advantage or are culturally meaningful. A normative river, a river with clean water, a river with fish, a river with ecological integrity is one such system because it allows essential organic and inorganic processes to function that are directly beneficial and meaningful to the cultures with connections to it. These benefits are clearly recognized and imbedded in some of the cultures within the Yakima River basin, the Columbia River basin, the Pacific Northwest, and at the National/International levels.

Rivers are part of the basic cultural geography of almost all human groups, but the cultural perception of and relationship to a river varies widely and is subject to profound systemic change -particularly when cultural benefit thresholds are being approached or have been crossed. This is the case with the Yakima River, since the river and its tributaries have been the subjects of intense legal scrutiny for over 100 years.

The various systems of policies, laws, and regulations that govern water distribution and its uses are interactive with culture at the local, regional, and national scales (Fraser, 1996). Cultural ecological history is important, for without it there is no geographic context, no chance for understanding. Much has been written about the Yakima River and the landscapes it fosters and supports (MacDonnel, 1999). Indeed, entire rooms have been filled with reports and maps that describe, explain, and justify strategies for planning, building, maintaining and enhancing the complex alterations of the Yakima River basin. However, the culture is changing, triggering a systemic metamorphosis in the value of the river and its water (Yerxa, 1997).

Some cultural members now place a high value on rivers that function like rivers. Plant and animal life is associated with clean flowing water to symbolize a perceived "naturalness" in the New West. Functioning rivers and the life they support have become a powerful symbol of the New West, particularly the Northwest, and specifically in the Yakima River basin.

New uses have emerged as human populations expand and landscape capitalization increases. A variety of recreation activities are firmly imbedded in the landscapes of the

Yakima River basin. Primary, secondary, and even tertiary homes are built along the river or in view of it. Subdivisions and developments, even when they alter normative processes, are named for what they most profoundly affect, i.e. Stone River and Riverview. Towns and cities feature the river in parks and parkways while concurrently using it for a source of water and as a waste disposal mechanism. This is the power of culture -it works by assigning meaning to objects, places, landscapes, and regions. While it is clear that people need to perceive that the river is a river, they also need water to grow crops and for a variety of activities essential to maintaining their expanding cultural ecology, i.e. for resorts, golf courses, waterslides, and lush, green lawns. Resources are cultural appraisals, and these appraisals change. The history of shifting appraisal and use is the primary force directing the structure and function apparent in the cultural ecology of the Yakima River basin. Its effects are perhaps most evident in the large alluvial floodplains.

The Cultural Ecology of the Yakima River Floodplains

The alluvial floodplains of the Yakima River are a critical component of the Valley Basin landscape. The naturally structured and functioning floodplains with all their constituent parts and regional interactions have been transformed to floodplains conditioned by human behavior. The current diversity of this behavior with respect to alluvial floodplain dynamics ranges from the obvious irrigation diversions, sewage treatment facilities, shopping malls, permanent residences, summer homes, golf courses, jet skis, fly-fishermen, subsistence fishing, cattle ranching, logging, gravel mining, landfills, RV camping, race car tracks, railroads, freeways, hydroelectric plants, wrecking yards, squatters, greenways, spray fields, dikes, gravel pits, row cropping, truck-gardens, and industrial agriculture to vaguely understood interactions of human induced effluents, altered groundwater flow paths, introduction of exotic species, and bridge crossings, to name a few. Each activity and its associated landscape structure and function has ecological consequences at the place or site scale, and when viewed in a cumulative context, forms a complex cultural landscape focused on the Yakima River (Johnson, 1994). It is this interaction of people and river basin that is the subject and verb of the Yakima River's ecology. Clearly, this interaction is a primary and powerful force in the evolution, persistence, and extinction of landforms, habitats, populations and organisms -including humans.

It is in the context of the cultural ecology of the Yakima River basin that the story of floral and faunal evolution, persistence, and extinction is understandable, and through which management opportunities are made operational. The story holds five broad themes:

- Changes in the way water is captured, stored, and delivered to the streams and rivers
- Changes in how the fluvial/hyporheic systems are connected
- Changes in the temperature and organic and inorganic contents of water in the system
- Changes in the biophysical interactions related to the fluvial/hyporheic system
- Changes in why, where, and how, cultural systems use, alter, preserve, restore, and enhance ecological systems

For example, once a key element of the basic food economy of Native Americans, fishing is now practiced from the delta to the glacial lakes and their tributaries. The cultural diversity expressed by this practice reflects the cultural diversity of the Yakima River basin. Although all fishing is predatory, its cultural meaning is extremely varied while its geographic patterns are directly reflective of broader cultural patterns. Subsistence fishing persists from the delta through the large alluvial floodplains encompassed by the agricultural landscapes. Catch and release fly-fishing dominates within the canyons, alluvial floodplains, and glacial valleys of the upper Yakima and Naches basins. Trolling and still-fishing dominate the once normative glacial lakes and the constructed Rimrock Reservoir. Gravel-pit ponds serve as bank fisheries and are among the most intensively fished locations in the river basin. Both the people and their prey are highly diverse, ranging from lawn chair bait fishermen at Bateman Island taking catfish, bass, and crappie, to guided international "sportsmen" catching "wild rainbow" in the upper Yakima River. The cultures represented derive from the continents of Asia, Europe, Africa, and North, Central, and South America, through the urban landscapes of Puget Sound and the urban-rural landscapes of the Yakima River basin. The various species of fish, although primarily evolved in North America, have been culturally transformed and their evolutionary potential reset.

Resource Management

It is within the broad context established by cultural ecology operating internal and external to the Yakima River basin that preservation, enhancement, and management of fish and wildlife proceeds. How the details of normative river ecology, connectivity, structure, and function of the biophysical environment are realized will, in large part, determine the evolutionary processes of adaptation and survival for most populations.

For thousands of years human populations have been involved in the management of resources in the Yakima River basin, but the land-use patterns of the last 100 years stand apart as very different (Uebelacker, 1980; 1984; 1986). This period is marked by initial attempts at "enhancement" through the re-introduction of previously extirpated species (elk, antelope, bighorn, etc.), and the introduction of exotic species (bass, walleye, pheasants, chucker etc.). Large-scale plantings, habitat enhancement, and acquisition projects focused on maintaining harvestable populations (Oak Creek Game Range, Lt. Murray Wildlife Area, Colockum Wildlife Area, etc.) followed these enhancement efforts.

These patterns of management were successful, and viewed as acceptable approaches to fish and wildlife enhancement. The legacy of this tradition is not only imbedded in landscape biophysics, but also in meaningful cultural practices. The "silver" fisheries located in the irrigation reservoirs, the "wild rainbow" fisheries in the upper Yakima and Naches rivers, and elk hunting are examples. To some extent these historic management traditions continue in the put-and-take fisheries of the gravel pit ponds, reintroduction of coho, and the increasing cultural importance of the bass fishery in the lower Yakima River. It is necessary to realize how closely intertwined resource management and culture practices are. In the end they become almost inseparable (Haydon, 1997).

From late 1970, and up to the present, a new direction in resource management emerged. Recognition of dramatic shifts in land-use practices and the accompanying decrease of fish and wildlife habitat drove this change. This recognition occurred at international, national, regional, landscape, and place scales, and was related to an increasing ecological knowledge of how biophysical interactions were structured and functioned. Management strategies shifted. In the Yakima basin the change was manifest through radical shifts in the hydrograph (flip-flop), and the monumental efforts directed at fish passage through the historically transformed maze of connectivity. Furthermore, new and significant “Supplementation Facilities” were constructed through tribal, federal, and state cooperation that gave substance and focus to preservation, recovery, and maintenance of aquatic resources. Habitat acquisitions for both fish and wildlife expanded; however, unlike earlier acquisitions the new pattern is focused on much smaller land parcels and motivated by “normative” ecosystem concepts as described in the following quote:

We recognize that, because we are dealing with an ecosystem that has sustained extensive human development for over 150 years, numerous social and biophysical constraints exist for enhancing normative conditions. The challenge before the region is to reach consensus on the extent to which these constraints can be relaxed or removed to achieve Fish and Wildlife Program goals. Nevertheless, we believe strongly that approaching more normative ecosystem conditions is the only way in which Fish and Wildlife Program goals for recovery of salmonids and other fishes can be met (Independent Scientists, 1996:19).

Although flip-flop was implemented to benefit anadromous fish spawning in the upper Yakima River, this legal compromise with irrigation interests radically transformed the hydrograph of both the Yakima and Naches rivers and further interrupted the biophysical environments of all downstream reaches. It proved again that resource managers can not do just one thing, and perhaps more importantly, amplifies the essential requirement of re-establishing and maintaining normative processes (Stanford et al., 1996). Indeed, the existing hydrograph of the Naches River is without a corollary in the natural riverine processes of Western North America, unless it would be the sudden draining of a glacial or landslide formed lake in late fall. However, this would have been a one time event, and not repeated annually for a quarter of a century. The hydrograph of the upper Yakima River now resembles a receding glacial system under a climatic scenario of advanced global warming, where flow is rapidly truncated due to the sudden onset of colder temperatures in the first weeks of September. Clearly, a return to a more normative hydrograph is not only desirable, but required.

Recently, management expanded to encompass the acquisition of remnant habitats that contain vestiges of structure, function, and ecological integrity -habitats with the potential for preservation and restoration. These are primarily activities initiated by federal, tribal, state, and some county and municipal entities attempting to partner with industry, conservancies, foundations, and citizens. Acquiring and reconnecting habitat, and re-establishing normative processes are essential for long-term success of threatened and endangered species restoration. Its success depends on informed decisions based on monitoring ongoing and proposed land-use, ecological modeling (Ecological Diagnosis and Treatment (EDT), climatic, watershed, hydraulic, and future landscape conditions), and the research to support such efforts. Unprecedented in the history of the basin, these approaches are driven by culturally meaningful and legally mandated goals for preservation, restoration, and enhancement of the basins ecological integrity.

Fish Habitat

By Major Drainage

The Yakima subbasin has, rather arbitrarily, been divided into 11habitat areas. This pattern of subdivision is proposed for the following reasons:

- Environmental similarity with respect to sequences of confinement and unconfinement

- Gross accessibility to salmon and steelhead
- Hydrographical similarity
- Relative use by various species and/or races of salmon and steelhead
- Environmental similarities with regard to water quality.

The 11 habitat areas are:

1) Headwaters reaches and tributaries. These areas include all streams and reaches upstream of impassible storage dams.
2) Upper Yakima mainstem. The mainstem Yakima from the Naches confluence to Keechelus Dam.
3) Upper Yakima tributaries, including the Kachess River, Big and Little Cr., the Cle Elum River below Cle Elum Dam, the Teanaway River and its three forks, Swauk Cr., Taneum and Manastash Cr., the Wilson/Naneum system and Reecer Cr., Umtanum Cr. and Wenas Cr.
4) Naches Mainstem, from RM 0 to 44.5, the confluence of the Bumping River and the Little Naches River.
5) Naches Tributaries, including Cowiche Cr., the Tieton River below Rimrock Dam, the Little Naches River and the Bumping River below Bumping Dam.
6) American River .
7) Middle Yakima mainstem. The mainstem Yakima from the Naches confluence to the tailrace of Sunnyside Dam.
8) Lower Yakima mainstem. The Yakima mainstem from Sunnyside Dam to the Columbia confluence.
9) Ahtanum Creek
10) Toppenish Creek
11) Satus Creek

Headwater Reaches and Tributaries

These areas were made inaccessible to salmon and steelhead by impassible storage dams. Yet most of these streams are relatively pristine, occupying watersheds that are largely undeveloped. Some idea of the magnitude of the loss the fishery sustained when these areas were blocked can be gained from a recent EDT simulation. This simulation entailed only the restoration of access above the dams; otherwise the areas were modeled with current environmental conditions. This simulation indicated that the headwaters areas in the Naches drainage (primarily the North Fork of the Tieton) would be capable of sustaining a population of 350 spring chinook with a productivity of 3.8 adult progeny per spawner. Comparable figures the headwaters areas in the upper Yakima (primarily the upper Cle Elum drainage) were 328 adults and 2.7 adult progeny per spawner. As these figures are quite similar to those for the American River, it would not be inaccurate to say that the loss of this habitat was roughly comparable to losing two American Rivers. Listed by dam, the most important reaches and tributaries in this group are:

- Cle Elum Dam: the 18.4 miles of the Cle Elum River from the point of lake entry to Hyas Lake, the 3.2 miles of the Cooper River below an impassible falls and the 7.2 miles of the Waptus River below an impassible falls.
- Keechelus Dam: Approximately seven miles of Gold Creek.
- Kachess Dam: About 1.4 miles of Box Canyon Creek and half a mile of the lake interior reach of the Kachess River (both blocked by falls).

- Rimrock Dam: About 1.5 miles of the (now inundated) Tieton River between the dam and the former confluence of the North and South Fork of the Tieton River, about 22 miles of the North Fork of the Tieton River and four miles of the North Fork tributaries of Clear Creek and Indian Creek. Although the South Fork of the Tieton is also blocked by Rimrock Dam, there is a waterfall on the lower South Fork that is now inundated by Rimrock Reservoir. It is therefore possible that the South Fork would remain inaccessible to salmon and steelhead even if passage could be restored over Rimrock Dam.
- Bumping Dam: About five miles of Deep Creek below an impassible falls and a mile of the lake interior reach of the Bumping River below a another impassible falls.

From the perspective of salmon and steelhead production, the loss of the upper Cle Elum River and the North Fork of the Tieton River were easily the most significant. The lower eight miles of the North Fork Tieton flowed through an area once known as McAllister Meadows, and now known as Rimrock Reservoir. This was a low gradient, complex alluvial reach much like the American River, and was a major spawning area for spring chinook and an important Indian fishing area. Upstream of McAllister Meadows, the North Fork is, even today, somewhat steeper (gradient ~2.5%), with larger substrate and less complex channel structure, but an abundance of large woody debris. Written documentation that coho and steelhead utilized the North Fork Tieton has not been found, although accessibility to spring chinook and habitat quality alone would argue that they did. The upper Cle Elum River was and is remarkably complex, containing a large, unconfined distributary fan near the lake, a confined canyon reach, a moderately steep (1.5 – 4% gradient) alluvial reach, and two lakes, one at the headwaters and one dividing two low gradient (0.5 – 1.0% gradient) lake outlet reaches with abundant, clean spawning gravel, an intact riparian corridor and plentiful large woody debris. Like the North Fork Tieton, it is known that the upper Cle Elum supported spring chinook, as well as sockeye and another important Indian fishery. Although documentation that the upper Cle Elum was used by coho and steelhead does not exist, there is no reason to believe they did not.

The other streams on this list, as well as many tributaries to the Cle Elum and North Fork Tieton that were not mentioned, are cold, small and often rather steep (gradient >4%). Some were probably negotiable by steelhead, although probably not spring chinook and coho. Like the larger streams on the list, they are also relatively intact. All of the existing storage reservoirs currently support populations of adfluvial bull trout, which spawn in the larger tributaries including the upper Cle Elum River, Box Canyon Creek, the lake inlet reach of the Kachess River, Gold Creek, and especially Indian Creek the South Fork of the Tieton River. Clear Creek Dam, on the lower North Fork of the Tieton several miles upstream of Rimrock Reservoir, has a fish ladder. However, probably because of insufficient attraction flow, the ladder is not used by bull trout. Therefore, the North Fork of the Tieton contains only a small resident population of bull trout. Adult migration into and out of Box Canyon Creek, the primary spawning tributary to Kachess Lake, may be affected by the annual drawdown of the lake. As the lake is drawn down, the exposed stream channel on the lake bottom can become ill defined as it flows across the permeable lake sediments and may become too shallow for bull trout passage. In the fall of 1996, Reclamation constructed a single channel through the inundation zone. The project was successful in 1997 and 1998, but under some circumstances passage problems may still persist particularly for adults returning to the reservoir. Similar passage problems for bull trout also occur in the Kachess River as it annually dewaters above the reservoir inundation zone.

Upper Yakima Mainstem

This large area, covering roughly 100 miles of river and 20% of the wetted area of the drainage exclusive of reservoirs, currently supports over 60% of spring chinook production basin-wide. It is estimated to have supported an even larger proportion of spring chinook production historically, as well as the bulk of steelhead and coho production. In the latter respect, the historical upper Yakima mainstem differs from the upper Yakima of today, in that coho have been extirpated from the area and steelhead all but extirpated.

Structurally, this area consists of three complex, alluvial reaches separated by two confined canyon reaches. The lowermost alluvial reach is bounded roughly by the confluence of the Naches River and Wenas Creek, the middle reach by the confluences of Wilson Creek and Taneum Creek, and the upper reach by the Cle Elum River confluence and Keechelus Lake. The lower canyon, the Yakima Canyon, extends roughly from Wenas Creek to Wilson Creek, while the upper canyon, the Ellensburg Canyon, lies between the confluences of Taneum Creek and the Teanaway River.

Naches River to Wenas Creek Dam.

The lowermost alluvial reach is roughly 10 miles long and has been severely degraded. Much of the floodplain has been overgrazed for many years, a very large spray field borders one bank and a large gravel mining operation the other. Much of the reach is now confined between poorly constructed levees protecting the gravel mining operation and various developed properties. Riparian vegetation is sparse, streambanks have collapsed, the width to depth ratio is large and large woody debris extremely scarce. Roza Dam is just above the reach, and diversions into Roza Dam strongly affect instream flows during the irrigation season. It has been a routine practice of the Bureau of Reclamation, which operates Roza Dam and the protective screens at the headworks of Roza Canal, to lower Roza pool in the fall to maintain the screens. This practice results in the discharge of large quantities of silt collected behind the dam. Consequently, substrate in the area is deeply imbedded and contains a high proportion of fines. Historically, this reach consisted of a number of large, shifting channels, a great many spring brooks, and scattered clumps of cottonwood. Large woody debris was probably abundant, as the reach was the first structurally complex area below the Yakima Canyon, which clearly was a transport reach.

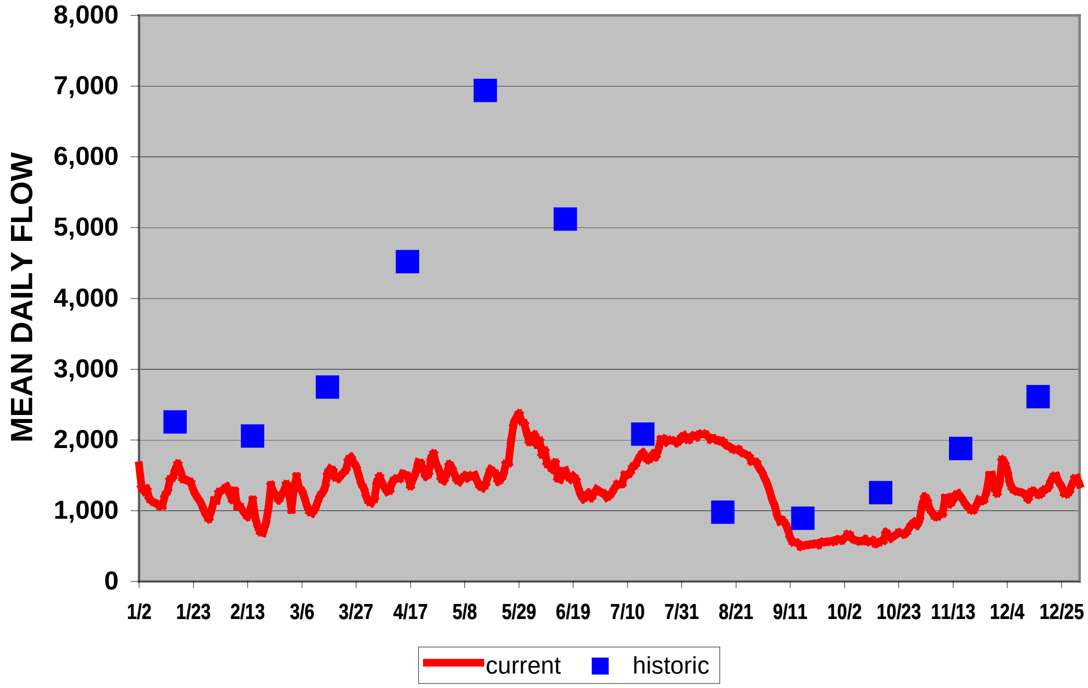


Figure 43. Current (1994-2000) mean daily flow and historical mean monthly flow, Yakima River below Roza Dam.

Figure 43 shows mean daily flow for the period 1994 – 2000 in the Yakima River below Roza Dam (USBOR Hydromet data), and historical mean monthly flows for the same site (HKM Engineering 1990). The effect of river regulation, and especially the withdrawals at Roza Dam, are clearly evident. The spring freshet has been totally eliminated, winter flows are lower than normative, and flows during the peak of irrigation season are slightly higher than normative. Hourly flow fluctuations below Roza Dam, as well as in the Yakima Canyon upstream, can be as large as 6%, but are usually 2-3%. These fluctuations are caused by fluctuations in upstream irrigation return flows. The distinctly non-normative hydrograph in this reach is believed to have an adverse impact on juvenile salmonids, either by downstream displacement or by dewatering shallow shoreline areas and stranding juvenile salmonids and their insect prey. This kind of hydrographic impact, to greater or lesser degree, is found in all portions of the upper Yakima mainstem.

Note that "current" flows are expressed in terms of means over the years 1994-2000. This is because the USBOR has implemented significant changes in river operations since 1994. These changes include the attempt to maintain minimum flows during winter reservoir refilling at certain locations and the attempt to constrain ramping rates (quick changes in flow and water surface elevation) to one two inches per hour for flow decreases and two inches per hour for flow increases. Recently, the Reclamation has also attempted to ensure that releases from Cle Elum Dam are large enough to keep a large anastomosing/side channel complex on the lower Cle Elum from being dewatered. In fact, at last count, there were some 15 reach-specific flow objectives intended to benefit fish that are negotiated annually between the Reclamation and the Systems Operations Advisory Committee (SOAC), a court-appointed advisory.

Although floodplain gravel mining has resulted in some long-term damage, the reach has potential for significant habitat rehabilitation. The levees could be selectively opened, set back or removed. A spring brook, modified to serve as an irrigation canal known as

Taylor Ditch, runs through the floodplain and could provide rearing habitat if a riparian area was reestablished and large woody debris was added. An average of 6.3% of the upper Yakima stock (4% of all stocks) has spawned in a series of riffles at the upstream end of the reach, and the largest single spawning concentration of upper Yakima steelhead is found in the Yakima mainstem between Roza Dam and Ahtanum Creek. The deep pools found in some number above Wenas Creek as well as a number of spring brooks provide winter habitat for both salmon and steelhead juveniles, although low winter flows may occasionally impact mainstem habitat adversely.

Yakima Canyon, Wenas Creek to Wilson Creek

Most of this 25-mile reach lies in the deep, steep-walled Yakima Canyon. Almost continuously, the river is bordered on the right bank by a railroad embankment and the left by a highway. Except for a pool upstream of Roza Dam, this reach consists primarily of fast, moderately deep runs. There are very few riffles or gravel bars and a limited number of pools – usually eddies on the inside of sharp bends. This is a transport reach for large woody debris, which is almost entirely absent. Riparian vegetation consists of a fringe of reed canary grass and willows, and an occasional isolated Ponderosa pine. The riparian vegetation is denser on the right bank, presumably because of vegetation control by the DOT. Except for several stable islands some hundreds of yards long, a half-mile natural side channel and a 1,300-ft man-made “rearing alcove” built on the right bank just below the confluence of Roza Creek, there is no off-channel habitat in the canyon. Substrate is primarily cobble and large gravel, is moderately embedded, and contains a considerable proportion of fines. A cloudburst in the summer of 1998 triggered over thirty landslides between Roza Dam and McPherson Canyon. Many of these landslides have narrowed the river by half and created large downstream eddies.

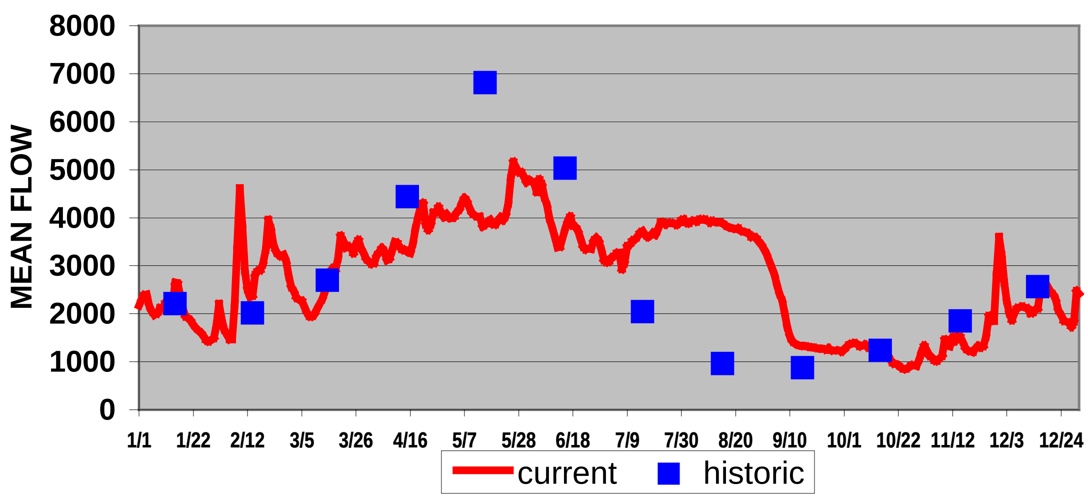


Figure 44. Current (1994-2000) mean daily flow and historical mean monthly flow, Yakima River in the Yakima Canyon (Umtanum gage)

Figure 44 is the current and historical hydrograph for the Yakima River near the mouth of Umtanum Cr (RM 139), about mid-way through the canyon. The general pattern seen throughout the upper Yakima is once again evident: a diminished spring peak, unnaturally low flows in the winter, and a distinctly artificial period of high flow in the summer. The latter aspect of the hydrograph, in combination with the structural simplicity of the channel and the lack of large woody debris, is perhaps the most important feature of the

Yakima Canyon from a fisheries perspective. Although prey organisms are plentiful and conditions are hydraulically suitable for large parr and adult trout, the velocity is simply too great for smaller life stages. The combination high summertime flows and scarce “velocity cover” has drastically limited the quantity and quality of rearing habitat for fry, especially for rainbow-steelhead fry, which emerge in late June and July. This lack of nursery habitat prompted the Yakama Nation to install 22 forty-foot boulder barbs throughout the reach in 1995, in an attempt to create additional slackwater eddies for rearing fry, as well as to provide interstitial habitat for overwintering.

The structure of the river in the Yakima Canyon may not have been radically altered since the area was developed. Certainly the river is more confined than it was historically, but is unlikely it was substantially more complex. The natural confinement of the reach is simply too great for the development of an extensive system of multiple channels, and the very high unregulated flows in May would have kept large woody debris accumulations to a minimum. Except for the current abundance of reed canary grass, riparian conditions also would not have been qualitatively different. The main difference is the hydrograph would have been reaching its annual low point just as rainbow/steelhead were emerging.

Wilson Creek to Taneum Creek

This reach flows is bounded by two significant tributaries and receives another significant tributary, Manastash Creek (RM 155) near its center, as well as a number of smaller streams such as Reecer and Dry Creeks. The city of Ellensburg borders most of its left bank. before development it was undoubtedly one of the major salmon and steelhead producers in the basin. While not so complex as some alluvial areas in terms of main channel anastomoses, there were large alluvial fans where major tributaries entered the river. These fans were dissected by multiple distributary channels and the entire complex of mainstem and tributary side channels represented a tremendous amount of structural complexity. Mainstem channels flowed through patches of cottonwood alternating with more recently disturbed areas fringed with willows and dogwood. As evidenced by the many islands still in existence that owed their formation to gravel trapping by log jams, the area also contained abundant large woody debris. After flowing out of the mountains on either side of the Kittitas Valley, all of the tributaries flowed through eight to ten miles of low gradient valley bottom before entering the Yakima. These valley reaches were complex anastomoses bordered by dense growths of willows and wetlands. Therefore, the area provided complex large river habitat for spring chinook spawning and rearing, low-velocity valley bottom tributaries for coho rearing, and steeper, pocket-water upland tributary reaches for coho and steelhead spawning.

Today many of the mainstem side channels have been filled or cut off , a history of gravel mining and agricultural activities have severely degraded the riparian corridor, and extensive channelization and diking, sometimes on both banks, have increased velocities and washed away many of the distributary channels. Because Insterstate 90 borders much of the river above Manastash Creek, where agricultural development is also more intense, diking, riprapping and channelization has been concentrated in this area. Consequently, about three fourths of the river above Manastash has been narrowed to a single thread, leaving a considerable number of isolated side channels. Bank sloughing is common, the riparian corridor is nonexistent or severely degraded, and large woody debris has been swept away by diking-induced increases in water velocity. Below Manastash most of the river still has multiple channels as well as a modest amount of large woody debris, some of which is provided by the remnants of the original cottonwood galleries. The area below Manastash has relatively more riffles than the area above, which is a run with some deep pools. A major impact to both halves of this reach is the stranding of fry and juveniles in remaining side channels when flip-flop or irrigation-related flow fluctuations isolate or dry up remaining side channels. Otherwise, the impacts of the regulated hydrograph are qualitatively similar to those described for the Yakima Canyon but less severe because of a greater degree of habitat complexity.

As impacted as it is, this reach still has tremendous potential for restoration. A considerable degree of normative character could be regained simply by removing or setting back levees and allowing the riparian vegetation to regenerate naturally. This reach has been identified in the Bureau of Reclamation's "Reaches Study" as well as the initial EDT analysis as one of the key reaches for anadromous fish production.

Taneum Creek to the Teanaway (10 miles)

Swauk Creek flows into this reach, all but the upper three miles of which flows through the Ellensburg Canyon. The river in Ellensburg Canyon very closely resembles the river in Yakima Canyon, with the exceptions of having relatively more (and very deep) pools below Swauk Creek, having a much cleaner substrate and providing side channel habitat over perhaps ten percent of its length. Also like the Yakima Canyon reach, the biggest impacts are not structural but hydrographic.

The Bureau's "Reaches" study has identified a very important alluvial reach the upper three miles of this section. The very complex alluvial reach referred to begins about half way between Cle Elum Lake and the confluence of the Teanaway River and ends about half way between the Teanaway and Swauk Creek. The primary zone of upwelling and braiding is around the Teanaway-Yakima confluence and includes the lower half mile of the Teanaway. This entire flood plain is largely intact, but is influenced by regulated flows from Cle Elum, Kachess and Keechelus Lakes, abstraction via Easton Diversion, several diversions on the Teanaway and road and railroad revetments throughout the reach. The Teanaway-Yakima confluence area has substantial restoration potential because the land is not heavily developed and because remnant backwaters and spring brooks are present in spite of the road berms and bridge revetments.

Teanaway to Keechelus Dam (40 miles)

Excluding the American River, this reach provides perhaps the most pristine fish habitat left in the basin. It is certainly the most important single reach in the basin as well as the most threatened. It is the premier spring chinook spawning and rearing area – about 50% of all spring chinook spawning in the entire basin occurs in this reach and over 75% of the upper Yakima stock spawning -- and could be the premier area for restored populations of coho and steelhead as well. However, the amount of floodplain (and floodway) that has been platted, combined with the laxity of enforcement of Shorelines regulations in Kittitas County, represent a potential for disastrous overdevelopment (Johnston 1995).

The character of the river changes just below the confluence of the Teanaway. From Keechelus Dam to the Teanaway, the vegetation community lies within a mesic zone dominated in the uplands by Douglas fir *Pseudotsuga menziesii* and Ponderosa Pine *Pinus ponderos*a. The remainder of the Yakima River lies within a xeric vegetation zone dominated in the uplands by sagebrush *Artemesia tridentata* (Franklin and Dyrness 1973). A visible boundary between these vegetation zones exists along Bristol Canyon, northwest from Ellensburg along Highway 10, where the vegetation changes from *Abies grandis-Pseudotsuga menziesii* to shrub steppe with *Artemsia tridentat*a.

Basically from the Teanaway upstream, the river flows through a forest which changes from primarily Ponderosa pine to primarily Douglas fir above the Cle Elum. This is and was a major large woody debris recruitment area. The large volumes of wood in the river, combined with a lack of natural confinement and perhaps a greater frequency of floods and disturbances, create a very complex river system. Almost the entire reach was anastomosing, springbrooks, wetlands and sloughs were common, and large log jams and debris piles were found throughout. High flows and the scour associated with large woody debris created numerous pools and clean gravel bars, while dense, mature conifers along the banks created deep undercuts and maintained stability. The reach receives several major tributaries – the Teanaway, Cle Elum and Kachess Rivers -- as well as numerous small tributaries such as Big, Little and Tucker Creeks. While the Teanaway and Cle Elum are low gradient, alluvial streams, the smaller tributaries provided the steeper, pocket-water type habitat favored by steelhead. The unconfined area around the Cle Elum confluence historically included a very large and complex alluvial fan through which both rivers had carved an anastomosi several miles wide (USBOR archival map). Collectively, these conditions add up to ideal habitat for salmon and steelhead.

A substantial amount of the structure of the habitat between Keechelus Dam and the Teanaway still exists. Several miles of the river in the vicinity of the city of Cle Elum has been diked and riprapped on both sides, with predictable results[9], and a substantial proportion of the floodplain between the Cle Elum confluence and Easton Dam has been developed for summer homes. Where it borders such summer home areas, virtually all of the river has been diked and riprapped for flood protection, especially in the areas known as Sun Island. Summer home areas are invariably cleared to the water's edge, reducing large woody debris recruitment and cover for fry. The complex anatomosis around the confluence of the Cle Elum has been eliminated, as have a number of major side channels in the Elk Meadows area (Johnston 1995), but the majority of the various types of "off channel habitat" still exist.

The biggest risk in this reach is that the county is not protecting the floodplain and riparian habitat from being damaged by development. The critical area protection provided by Kittitas County is woefully inadequate. The reach is not accurately mapped for floodplain or wetlands, and Kittitas County uses this inaccurate data to approve developments even when it is obvious that the information is wrong. Even river side channels have been deemed "outside of the floodplain" because they did not appear within the floodplain on the official county maps.

While overdevelop is the greatest risk, it is still substantially a potential impact. The major ongoing negative impact is hydrographic. Figures 45, 46, and 47 depict, respectively, current and estimated historical flows in the Yakima River just below the Cle Elum confluence, just below Easton Dam and just below Keechelus Dam. The hydrograph at Cle Elum shows the usual changes: a diminished spring peak, and a greatly augmented, unnatural summer flow that drops off quickly to unnaturally low and less variable winter flows. The negative impacts of these hydrographic changes include:

- Displacement of fry unable to hold against unnaturally high flows.
- Stranding of fry and juveniles in side channels when flows are temporarily down-ramped for irrigation purposes or regularly reduced for flip flop.
- Downstream displacement of juveniles during the winter because perched overwintering habitat becomes inaccessible when flows are reduced for flip-flop and reservoir refilling.

[9] A portion of this dking entailed the isolation of a 2-mile bend of the main Yakima River. The YKFP Cle Elum Hatchery is located between this isolated riverbend and the current channel of the Yakima River.

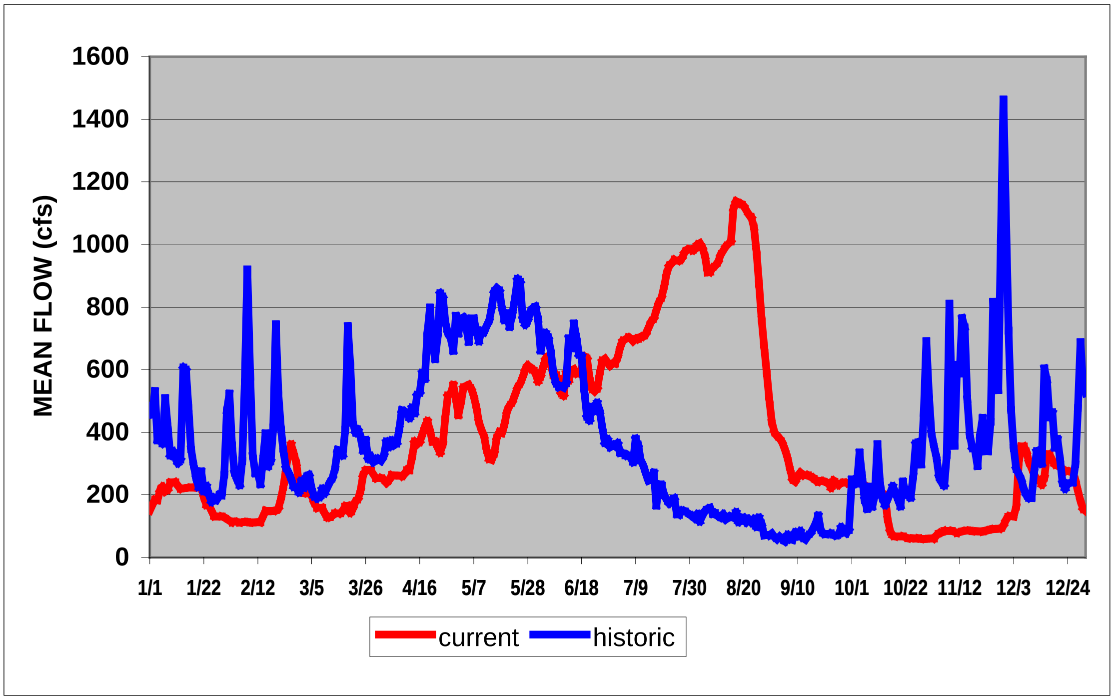


Figure 47. Mean daily regulated (current) and unregulated (estimated historical) flow, Yakima River below Keechelus Dam, 1994-2000

Figure 46 shows that the Easton reach suffers much the same problems except for a considerably lower probability of fry displacement by excessive summertime flows. Summertime flows are not so unnaturally high here because about 1,200 cfs is continually diverted into the Kittitas Reclamation District canal at Easton Dam. What Figure 46 does not show is the occasional episodes of extreme hour-to-hour flow fluctuations in this reach. The gate at Easton Dam does not function reliably, and a number of times over the past 25 years flows have been suddenly and drastically reduced during June and July, when salmonid fry are concentrated in shallow side channel areas. The worst of these flow fluctuations can be as much as several feet in an hour. Most side channels in this area are either dry or isolated at flows less than ~100 cfs. There were numerous times in 1987, 1988 and 1989 when flows were less than this: a minimum mean daily flow of 76cfs in June of 1989; minima in June and July of 1988 of 44 and 46, respectively; and a minimum mean daily flow of 39cfs on June 11, 1987, which included a bi-hourly flow estimate of 17 cfs. There is evidence that these flow fluctuations in the Easton reach substantially reduced smolt production for the entire basin the following year, undoubtedly because of the stranding of fry in dewatered side channels (Fast et al. 1991).

Figure 47 shows the current/historical hydrograph in the Easton-to-Keechelus reach. The hydrograph here is obviously an exaggeration of the non-normative pattern for the upper Yakima as a whole. Fry displacement may not, however, be so severe a threat as the hydrographic data indicate, because of the very high degree of structural complexity in the reach. The floodway above Easton Dam is very wide and filled with large woody debris, snags, live trees and brush; the likelihood of a fry finding a protected area, even at the highest flows, is great. A more significant problem is the very low flows that can occur in the winter – and that regularly did occur prior to 1994. Before 1994, there was a substantial period during almost every winter when flows were cut off totally or nearly totally, wiping out any winter parr or incubating eggs in the area. Since 1994, the Bureau has attempted to maintain flows above an absolute minimum of 30 cfs in this reach and, whenever possible, to maintain flows high enough to cover all redds deposited the preceding fall. Unfortunately, the latter goal cannot always be accomplished – the Bureau estimates water supplies will be inadequate roughly one to two years out of ten. In good years, there is enough water in Kachess Reservoir to execute a "mini-flip-flop": to meet upriver irrigation demand primarily with Kachess water (which enters Easton lake, below the spawning areas) during spawning while keeping flows out of Keechelus low enough to ensure enough water will be left to provide for their subsequent incubation as well as the next season's irrigation water. Again, 10-20% of the time, there will not be enough water in Keechelus and Kachess Reservoirs in the fall to do this. When such a season is shaping up the Bureau, in consultation with SOAC, determines whether the ladder at Easton Dam should be closed to prevent chinook from entering the area and depositing their eggs in an area that will be dewatered.

Wilson Creek to Taneum Creek

This 22-mile reach is bounded by two significant tributaries and receives another significant tributary, Manastash Creek (RM 155) near its center, as well as a number of smaller streams such as Reecer and Dry Creeks. The city of Ellensburg borders most of its left bank. Before development it was undoubtedly one of the major salmon and steelhead producers in the basin. While not so complex as some alluvial areas in terms of main channel anastomoses, there were large alluvial fans where major tributaries entered the river. These fans were dissected by multiple distribution channels and the entire complex of mainstem and tributary side channels represented a tremendous amount of structural complexity. Mainstem channels flowed through patches of cottonwood alternating with more recently disturbed areas fringed with willows and dogwood. As evidenced by the many islands still in existence that owed their formation to gravel trapping by logjams, the area also contained abundant large woody debris. After flowing out of the mountains on either side of the Kittitas Valley, all of the tributaries flowed through eight to ten miles of low gradient valley bottom before entering the Yakima. These valley reaches were complex anastomoses bordered by dense growths of willows and wetlands. Therefore, the area provided complex large river habitat for spring chinook spawning and rearing, low-velocity valley bottom tributaries for coho rearing, and steeper, pocket-water upland tributary reaches for coho and steelhead spawning.

Today many of the mainstem side channels have been filled or cut off, a history of gravel mining and agricultural activities have severely degraded the riparian corridor, and extensive channelization and diking, sometimes on both banks, have increased velocities and washed away many of the distribution channels. Because Interstate 90 borders much of the river above Manastash Creek, where agricultural development is also more intense, diking, rip rapping and channelization has been concentrated in this area. Consequently, about three fourths of the river above Manastash has been narrowed to a single thread, leaving a considerable number of isolated side channels. Bank sloughing is common, the riparian corridor is nonexistent or severely degraded, and large woody debris has been swept away by diking-induced increases in water velocity. Below Manastash most of the river still has multiple channels as well as a modest amount of large woody debris, some of which is provided by the remnants of the original cottonwood galleries. The area below Manastash has relatively more riffles than the area above, which is a run with some deep pools. A major impact to both halves of this reach is the stranding of fry and juveniles in remaining side channels when flip-flop or irrigation-related flow fluctuations isolate or dry up remaining side channels. Otherwise, the impacts of the regulated hydrograph are qualitatively similar to those described for the Yakima Canyon but less severe because of a greater degree of habitat complexity.

As impacted as it is, this reach still has tremendous potential for restoration. A considerable degree of normative character could be regained simply by removing or setting back levees and allowing the riparian vegetation to regenerate naturally. This reach has been identified in the Bureau of Reclamation's "Reaches Study" as well as the initial EDT analysis as one of the key reaches for anadromous fish production.

Taneum Creek to the Teanaway (10 miles)

Swauk Creek flows into this reach, all but the upper three miles of which flows through the Ellensburg Canyon. The river in Ellensburg Canyon very closely resembles the river in Yakima Canyon, with the exceptions of having relatively more (and very deep) pools below Swauk Creek, having a much cleaner substrate and providing side channel habitat over perhaps ten percent of its length. Also like the Yakima Canyon reach, the biggest impacts are not structural but hydrographic.

The Bureau's "Reaches" study has identified a very important alluvial reach the upper three miles of this section. The very complex alluvial reach referred to begins about half way between Cle Elum Lake and the confluence of the Teanaway River and ends about half way between the Teanaway and Swauk Creek. The primary zone of upwelling and braiding is around the Teanaway-Yakima confluence and includes the lower half-mile of the Teanaway. This entire flood plain is largely intact, but is influenced by regulated flows from Cle Elum, Kachess and Keechelus Lakes, abstraction via Easton Diversion, several diversions on the Teanaway and road and railroad revetments throughout the reach. The Teanaway-Yakima confluence area has substantial restoration potential because the land is not heavily developed and because remnant backwaters and spring brooks are present in spite of the road berms and bridge revetments.

Upper Yakima Tributaries

There are a great many tributaries in the 100 miles of the upper Yakima, and virtually all of them are fish-bearing, usually including at least one salmonid species. Because of their number, the description will focus only on those that currently support salmon or steelhead, as well as those known to be important to non-anadromous salmonids.

Most upper Yakima tributaries have been radically altered from their pristine state – so much so that it requires an act of disciplined imagination to see them as they probably appeared before development. Moreover, beyond the terse and narrowly focused field notes of Bryant and Parkhurst's stream surveyors in the 1930's (Bryant and Parkhurst 1950), very few documents can be found that describe either the habitat or the fish of these streams in historical times. Therefore, the descriptions of the historical steams that follow should be seen, except where specifically noted, as a combination of a handful of facts and an application of ecological generalizations.

It is worth repeating that this difficult and exasperating task of re-creating historical landscapes and fisheries is an important exercise. In general, it is important because it is the only way we can know what "good habitat" in the Yakima Basin is; the definition of normative is always basin-specific. In particular, it is important because the EDT model is at its core comparative, and the standard of comparison is the structure and function of the historical, normative ecosystem. Therefore, the more accurate is the description of the historical template, the more accurate the output of the model.

Wenas Creek

Wenas Creek is a right bank tributary that enters the Yakima at RM 122. Historically, it was probably a small but productive coho stream also utilized by steelhead. The mainstem of the creek ascends a broad, alluvial valley for 22 miles before branching into the North and South Forks, its major tributaries. Historical maximum and minimum mean monthly flows at the mouth have been estimated at 140 cfs in May and 15 cfs in September (HKM 1990). Below the forks the creek was unconfined, of moderate slope (1.2%), anastomosing, with a cobble gravel substrate; the forks and tributaries flowing off the slopes of Manastash Ridge and Cleman Mountain were steeper (3-4% gradient), pocket-water type streams with patch gravel. Riparian vegetation near the mouth consisted of cottonwood and willows, changing to alder/aspen/cottonwood/Ponderosa pine nearer the forks and Douglas fir in the tributaries. Beaver were probably numerous in the middle reaches, and beaver ponds and wetlands likely were common. Coho probably spawned primarily in side channels of the mainstem creek, and steelhead primarily in the tributaries, although spatial overlap probably occurred.

Except for the uppermost portion of the mainstem creek and its forks, the Wenas Creek of today bears no resemblance to the Wenas Creek of the past. An impassible storage reservoir was built at RM 15 in the early 1930's, blocking access to the upper drainage. A control structure at RM 12.0 diverts the stream into two channels, the "North" and "South" channels, to facilitate irrigation withdrawals. These channels reconnect six miles downstream. Summertime irrigation withdrawals from the creek and the channels remove all water between RM 9 and RM 14. Flows below RM 9 are intermittent, and only minimal where present. Substantial irrigation with well water in the lower valley likely contributes to low flows in the creek. These low-flow conditions persist into the winter as Wenas Reservoir is refilled. Below RM 9 the creek flows through areas heavily used for grazing, and riparian vegetation is virtually nonexistent. Lack of shading and low flows combine to generate summertime water temperatures in excess of 80 ^{o}F. Bank sloughing is common and the streambed often consists of mud and silt. Salmonids are not known to use Wenas Creek below RM 14.

Umtanum Creek.

Umtanum Creek enters the Yakima at RM 140, approximately in the middle of the Yakima Canyon. It is the only tributary of any size entering the Yakima Canyon. The stream supports rainbow and cutthroat trout, steelhead and various nonsalmonid species. Occasional steelhead spawning has been observed in the creek, and a radio-tagging study (Hockersmith et al. 1995b) indicated that about 10% of rainbow residing in the Yakima Canyon spawn in the creek. Bryant and Parkhurst (1950) report that coho spawned in the creek before the construction of Pomona Dam in 1890, suggesting that instream flows were much better historically than they are today. Access is currently limited to approximately RM 4.8 where a large gabion structure intended to protect a pipeline crossing is a total barrier to fish passage at all but flood flows. Were this problem corrected, access would be limited by an impassible falls at RM 8.0. Below the falls, Umtanum has generally good conditions with respect to its floodplain, channel condition, substrate, riparian condition and water quality. The main problem below the falls is low flows, which have a maximum of about 15 cfs in May and a minimum of 1cfs or less in September. The stream dried up at RM 10 because of a long history of overgrazing and subsequent down cutting. A riparian fencing project and restoration of beaver colonies above the falls might generate enough additional summer flows to increase productivity substantially.

Wilson/Naneum.

Wilson Creek, a left bank tributary that enters the Yakima River at the upstream end of the Yakima canyon (RM 147). The Wilson Creek watershed drains an area of 382 mi^2, second only to the Cle Elum River watershed among upper Yakima tributaries. The drainage consists of over a dozen small tributaries and several larger streams (Wilson, Naneum, Cherry, and Coleman Creeks) that flow out of Colockum Ridge and across 10-15 miles of valley bottom before entering the Yakima (Figure 48). The unregulated hydrograph has an estimated peak flow of about 440 cfs in May and a minimum of 35 cfs in September (HKM 1990). Once out of the hills, Wilson Creek and its tributaries formerly were primarily multi-channel streams, probably filled with beaver dams and ponds, flowing through dense willows and patches of cottonwoods and aspen. Steelhead and coho salmon spawned and reared in the system in sufficient numbers to have supported at least two major Indian fishing sites located in what is now the city of Ellensburg (The Selah Story 1989).

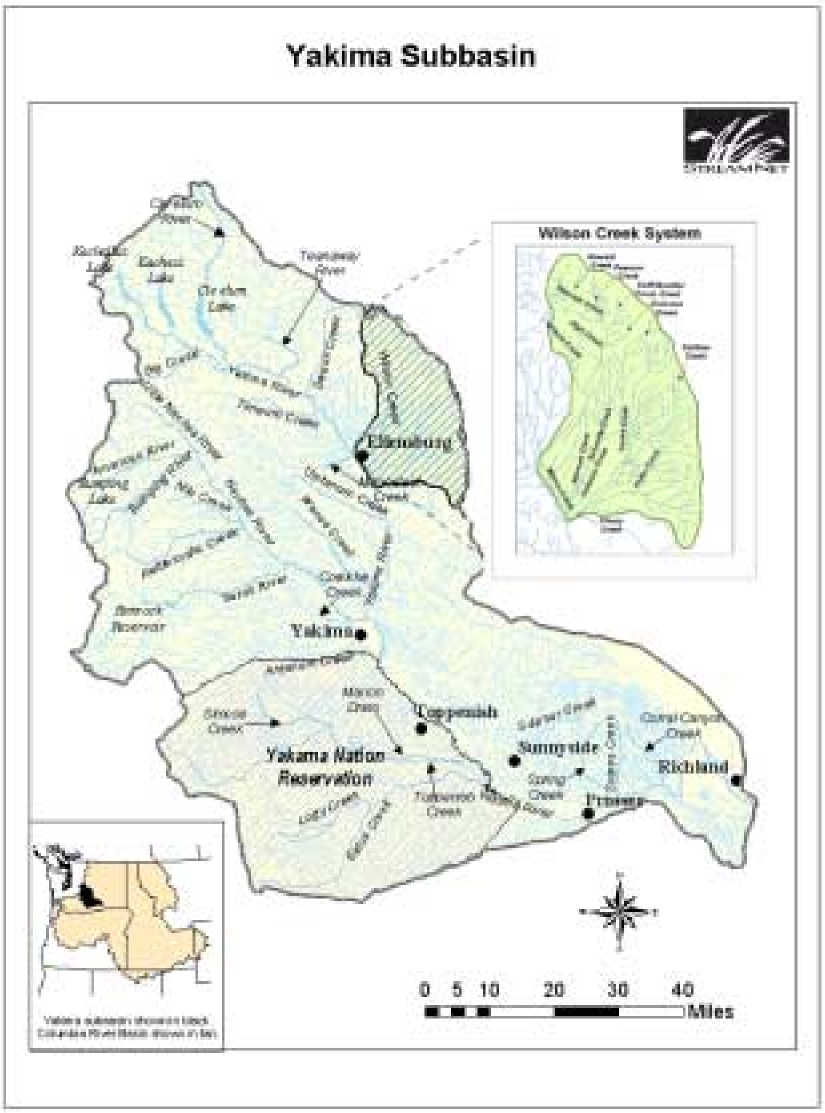


Figure 48. Yakima subbasin map showing the Wilson Creek system

Unfortunately, perhaps more than any other drainage in the basin, Wilson Creek has been wholly given over to irrigation. Many of the tributaries are used as irrigation delivery systems and have been re-routed, channelized and diked for that purpose; in such reaches the streams are straight, high velocity chutes with few pools, no large woody debris and poor riparian vegetation. Most have dozens of unscreened diversions and impassible check dams, and all pass through siphons underneath three large irrigation ditches – the Kittitas Reclamation District Canal, the Cascade Irrigation District Canal, and Town Ditch Canal– which in many cases represent passage barriers. In some cases, stream water is commingled with these large ditches, allowing fish to be entrained. Wilson Creek and its three man-made branches pass through the heart of Ellensburg, often in underground culverts, which may also represent obstacles to passage. Gravel quality and size distribution is good outside of the valley floor, but in the lower reaches irrigation priming and early season operations deliver high levels of fine sediment to the channels and urban runoff is discharged directly into Wilson Creek and its tributaries. Consequently, fine sediment levels are high in the drainage below Ellensburg. The riparian zones, for the valley portions of this watershed, are extensively impacted by grazing and other agricultural practices and highly variable in quality. Some riparian communities are properly functioning, while others are completely devoid of shrubs or overstory trees. Impassible irrigation check dams block access to all but the lower 24 miles of the drainage, but Yakama Nation staff have worked cooperatively with private landowners to install screens and fishways and to revegetate and fence riparian habitat, and have recently restored access to 10 miles of lower Wilson Creek.

Notwithstanding its many and serious problems, Wilson Creek and its tributaries represent a tremendous restoration potential for coho, steelhead and rainbow trout, and to a lesser degree for spring chinook as well. Even now spring chinook juveniles rear in large numbers in the lower 2-4 miles of Wilson, Cherry, Badger, Naneum and Coleman Creeks (Easterbrooks 1990), as do rainbow trout and steelhead juveniles. Steelhead spawners have occasionally been observed in various Wilson Creek tributaries (Fred Meyer FEIS, City of Ellensburg, January 1999;WDFW 1998), and wild rainbow and brook trout are found in large numbers in the forested upper reaches of Naneum, Wilson and Coleman Creeks (Geoff McMichaels, personal communication, 1998). An initial objective should be the restoration of safe adult and juvenile passage from the Yakima River to the headwater reaches of Wilson, Naneum and Coleman Creeks. With comprehensive, system-wide planning, diversions can be consolidated and water sources can be switched from Wilson Creek and its tributaries to one of the three large irrigation systems that pass through the drainage. As passage is restored progressively upstream, fisheries agencies should build upon the success the Yakama Nation has had in cooperatively working with private landowners to improve riparian conditions and reduce discharge of sediment into streams.

For many years, the Wilson Creek drainage has been considered a basket case. Only fairly recently have serious efforts been made to determine the actual production potential of the system and to begin resolving its access and habitat problems. The results of these efforts have been surprisingly positive. Although complex and time-consuming, feasible solutions to the problems afflicting the drainage do exist. Moreover, the watershed is simply too large and too intrinsically productive to be written off.

Manastash Creek, Taneum Creek, Big Creek and Cabin Creek.

Manastash is the first of four similar west-side upper Yakima tributaries – in ascending order by river mile, Manastash Cr. (RM 154.5), Taneum Cr. (RM 166.1), Big Cr. (RM 195.8) and Cabin Cr. (RM 205). All drain watersheds of moderate size – 50 to 95 mi^2 – and all have modest water yields, ranging from May peaks of ~175-490 to August/September low flows of 10-15 cfs. They have a similar structure, flowing through a low-gradient, generally unconfined section in near the headwaters, sometimes with multiple channels and spring brooks (South Fork Manastash), followed by a steeper canyon section with varying degrees of confinement and finally through 2-6 miles of low gradient valley bottom before entering the Yakima. There is an increasing gradient of precipitation as one moves upriver in this list, and mean monthly flows generally increase from Manastash to Cabin Cr, as does the frequency of flood disturbances and the incidence of channel instability. However, except for Cabin Cr, which suffers from massive clear-cuts over most of its upper watershed, channel instability is not a significant problem from a fisheries perspective. Riparian conditions – again, excepting Cabin Cr – are unusually good on these creeks, grading from dense alder/cottonwood that approach complete canopy closure in the valley to equally dense growths of alder/Douglas fir in the low-gradient upper reaches. The steep-sloped and rocky canyon sections of Manastash and Big Creek are fringed with dense growths of willow and alder. Substrate is cobble/gravel in the valley bottoms; boulder/cobble with patch gravel in the steeper canyon reaches; and clean cobble/gravel, often in the form of large gravel bars, in the uppermost reaches. Habitat complexity is not ideal in the lower reaches of any of these streams, which are now almost exclusively single channels providing pocket-water habitat (although there is evidence of limited anastomosing in the valley bottom sections of both Taneum and Manastash Creeks), with very little large woody debris.

Habitat complexity and large woody debris abundance increases dramatically in the upper reaches – e.g., in the South Fork of Manastash Creek above ~RM 10 (Buck Meadows), in the North Fork and South Fork of Taneum Creek (above RM 12.7) and in the Fishhook Flats area of the North Fork of Taneum Creek (RM 3 NF Taneum), and above Big Cr. Dam (RM 2.1) on Big Creek. Cabin Creek is once again an exception; its recent history of intensive logging has exaggerated a naturally flashy hydrograph to such a degree that large woody debris is swept from the system, and streamside clear-cuts preclude new recruitment. Manastash, Taneum and Big Creek are on the CWA Section 303(d) impaired water quality list for instream flow, and Cabin Creek is on the CWA 303(d) impaired water quality list for water temperature, with numerous excursions from water quality standards documented at the Forest Service boundary from 1989 to 1994. Maximum summertime water temperatures in the lower sections of all of these creeks can occasionally approach 70 ^{o}F (Johnston 1989), but these episodes are brief, diurnal fluctuations are large, and excessive temperature is not believed to be a serious problem on any of these creeks.

Historically, all of these streams supported coho and steelhead throughout and limited numbers of spring chinook in the valley bottoms[10]. In recent years, steelhead have occasionally been observed spawning in Taneum and Big Creek and spring chinook in the lowermost section of Manastash Cr. (Fast et al 1991). *O. mykiss* and spring chinook juveniles rear in some numbers near the mouths of all of these tributaries when they have not been dewatered by irrigation diversions, and rainbow trout are found in fair numbers in both the canyon and upper flats areas. Collectively, all of these streams have substantial production potential for steelhead and coho, and a modest potential for spring chinook.

Except for Cabin Creek, irrigation dams and/or withdrawals are the only significant factors preventing these streams from realizing their substantial current production potential. Six active diversions withdraw water from Manastash Creek between RM 1.4 and 5.7. Four of them are associated with dams that are partial or total barriers to all life stages, and none of them are screened. In the summer, Manastash Creek is dry between RM 1.4 and 3.0 and

[10] Bryant and Parkhurst document a “good run” of coho in Taneum Creek before 1910. It has been inferred from ecological similarities that what was true of one creek was true of all. Steelhead and spring chinook still spawn in several of these tributaries and so certainly also did so historically.

between RM 3.3 and 4.9. The lowermost 1.4 miles receives virtually nothing but groundwater return seepage, which amounts to 4-5 cfs at the mouth. The lower portion of Taneum Creek is heavily diverted, with 4 irrigation diversions in the lower 3.5 miles. Low flows in the lower 3.3 miles of Taneum Creek in the late summer and fall block spring chinook and coho from good spawning habitat upstream (CBSP 1990, WDFW 1998). Fishways and screens were, however, installed on all Taneum Creek diversions by 1990, leaving instream flow as the only remaining irrigation-related problem. Big Creek has two diversions, a small (2-3 cfs) berm diversion at RM 0.7, and a larger (10-15 cfs, 5-foot head) impassable diversion dam at RM 2.1. The lower diversion dam is easily passable to adults, but the upper dam has no fishway and an unscreened ditch (CBSP 1990). Big Creek is also heavily channelized downstream of RM 3.0, with associated channel instability and bedload deposition in the lowermost 0.25 mile (WDFW 1998). Big Creek has substantial perennial flows (~10 cfs in August 1988) upstream of the upper diversion, but flow downstream is ~1 cfs, most of which is leakage (CBSP 1990, 303(d) Decision Matrices). Flows are recharged by groundwater over the next mile, and increase to ~3 cfs at RM 1.2 (also in August 1988). Most of this recharge is subsequently removed at the lower diversion, and the stream is totally dry or intermittent from RM 0.6 to the mouth.

Clearly, fishways and screens could eliminate the structural access problems on all of these streams. The KRD Canal might be used to rectify the instream flow problems as well. All of these streams are intersected by from one to three branches of the South Branch of the KRD Canal. Although details, both legal and technical, remain to be resolved, there is clearly the potential for KRD to deliver water directly to users in the lower Manastash, Taneum and Big Creek watersheds, eliminating the need for diverting water from any of these creeks.

Unlike the other west-side upper Yakima tributaries, there are no irrigation dams or diversions on Cabin Creek. The major habitat impacts limiting salmonid production in Cabin Creek are access over a series of cascades and waterfalls between RM 3.1 and 3.8, and an extremely flashy hydrograph largely attributable to massive clear-cuts in the upper watershed. The nature of the falls above RM 3.1 in historical times is unknown, but it is at least possible that they did not present nearly so formidable barrier then as they do now. Precipitation in the watershed is heavy (>100 inches/year), and runoff is now extremely fast because of clear-cuts that extend from the water's edge to the ridge tops. Peaks flows have consequently become extraordinary for a stream the size of Cabin Creek, and the erosion to a natural cascade that may historically have been passable by steelhead must have been significant. Nevertheless, this cascade reach is currently impassable by any life stage, leaving only the lower 3.1 miles for spawning and rearing. Channel instability in this reach is, however, massive and regular, precluding successful spawning by any species and severely compromising the value of the reach for summer rearing or overwintering.

Swauk Creek

Swauk Creek is a left bank tributary to the upper Yakima River, entering at RM 169.9. Swauk Creek and tributaries drain approximately 100 mi^2, and support spring chinook (only juveniles present), steelhead (vestigial run), and bull trout (captured 200m upstream of mouth in 1993), as well as other resident salmonids and non-salmonids (WDFW 1998). Spawning coho were observed in the creek as late as the early-1960s (J. Easterbrooks, as cited in CBSP 1990), and a vestigial run of steelhead may still exist (CBSP 1990). Swauk Creek was historically a substantial producer of steelhead and coho, but probably was too steep, narrow, and shallow for spring chinook (CBSP 1990).

Although the drainage area of Swauk Creek is fairly large, precipitation is minimal and unregulated summer stream flows are now very low (CBSP 1990). Flows at the mouth vary from zero during the summer and fall to about 70 cfs in May. Historical flows, particularly base flows, are believed to have been greater.

Historically, Swauk Creek is believed to have included a series of short, flat, unconfined areas, through which the stream meandered in multiple channels. These areas were wet meadows, containing beaver dams and ponds, and functioned to conserve spring runoff and augment late summer and fall base flows. The elimination of beaver in the 1830's, in combination with a long history of mining, which reached its peak in the 1870's but still continues at low levels today, eliminated these areas. In particular, the operation of huge stream dredges lowered the water table and dried out the adjacent land. With no beaver dams to arrest it, erosion and drying continued and the critical water retention function of these wet meadow terraces was lost.

Today, the altered stream usually dries up or becomes intermittent somewhere between RM 3 and 5 (Johnston 1989). The lower three miles of the watershed are located in a steep, arid canyon. Progressing upstream, willows, alder and cottonwoods gradually increase until, by RM 8, the stream flows through a conifer forest of increasing density. Substantial recreational and commercial gold prospecting occurs on the main Swauk tributary, Williams Creek. A long history of suction dredging for gold has likely increased the presence of fines (embeddedness) in the substrate, impairing survival of salmonid redds (WDFW 1998). The substrate is composed mainly of large rock and boulders in the lower 2-3 miles, which are located in a steep-gradient arid canyon (CBSP 1990, WDFW 1998). The substrate upstream of RM 3 consists mostly of coarse rubble, with a patchy distribution of spawning gravel suitable for steelhead and coho spawning (CBSP 1990). The streambed appears stable throughout (CGSP 1990). Above RM 8, riparian condition is generally good upstream, with no areas of significant overgrazing (CBSP 1990, WDFW 1998). Water quality is fair/good, with temperatures in the perennial reaches in the 50s (F) in August 1988, but in the mid-60s (F) in the intermittent areas and pools (CBSP 1990). Two reaches of mainstem Swauk Creek are included on the CWA 303(d) impaired water quality list for water temperature. Blue, Williams, and Iron creeks (tributaries to Swauk Creek) are on the CWA 303(d) impaired water quality list for water temperature.

The "natural" -- *viz.,* not irrigation-related -- low flows throughout the system and the absence of flow in the lower 3-5 miles in the fall limit severely limit steelhead production, and totally preclude coho production (CBSP 1990). The streambed remains dry through early fall, precluding adult anadromous salmonid access into the upper watershed (WDFW 1998). Swauk Creek was proposed for inclusion on the CWA 303(d) impaired water quality list for impaired instream flow, but was not included due to any conclusive link between human actions and observed lack of instream flows. Upstream of RM 8, where the stream enters a forested zone, flows are marginally adequate through the summer (CBSP 1990). The Burke diversion (RM 7) is relatively small and is the only diversion on Swauk Creek. Flows below the diversion point are, however, so low that the water withdrawn may be the difference between low flow and no flow downstream.

Teanaway River

The Teanaway River is a left bank tributary to the Yakima, entering at RM 176.1. It is a large tributary, with a drainage area of 200 mi^2 (CBSP 1990). The mainstem is 11.7 miles long, and the number of miles accessible to steelhead in the North Fork, Middle Fork, West Fork and a number of small, North Fork tributaries is on the order of 16 miles, 12 miles, 8 miles and 3 miles, respectively. Lower fall flows can be expected to reduce accessibility to spring chinook and coho significantly. The Teanaway supports spring chinook, steelhead, rainbow trout and bull trout, as well as a number of other salmonid and non-salmonid species (WDFW 1998). Spring chinook currently spawn in low numbers in the mainstem and in the North Fork as far as Stafford Creek (RM 8.3). Steelhead have been observed spawning on a number of occasions in the mainstem and in the lower West Fork (Hockersmith et al. 1995; YN, unpublished data, 2001). Resident and fluvial bull trout were observed upstream of Dereux Campground in the North Fork in 1997, and juveniles have been observed in Jack Creek, Jungle Creek and in De Roux Creek, although spawning has been only in De Roux Creek (WDFW 1998). The status of Teanaway bull trout is considered critical.

The Teanaway was historically one of the top producers of spring chinook, steelhead, and coho in the Yakima watershed (Bryant and Parkhurst 1950, as cited in CBSP 1990). With restoration of a number of significant habitat problems, the physical diversity and size of the Teanaway guarantee it could still be a major producer. Indeed, a recent EDT simulation of Yakima Basin spring chinook indicated that that the Teanaway River was one of the top five portions of the entire basin in terms of restoration potential, and that if it were fully restored to historical conditions, productivity and equilibrium abundance would be doubled basin-wide. Suitable spawning gravels and gradients for all three species are present in most reaches of the mainstem and the lower portions of the forks, and are abundant in many areas. The upper reaches of the forks, as well as the lower reaches of a fair number of small, North Fork tributaries (De Roux, Eldorado, Johnson, Beverly, Jungle, Jack, Rye, Indian, Middle, Dickey, Lick, Stafford Creek Bear and Standup Creeks) could provide additional spawning habitat for steelhead and possibly coho (CBSP 1990).

The picture of the historical system built up during this EDT analysis is as follows (YN 2001; CWU Geology Dept workshop, 1995). All of the mainstem as well as the lower several miles of all the forks lies over deep alluvial deposits, and before development consisted of an unconfined, anastomosing network of channels. Beaver ponds are known to have been very numerous, and the wide valley of the mainstem and lower forks was largely wet meadow or wetland. This structural complexity not only benefited fry and juveniles, but also greatly reduced the destructive impact of floods within this area of high precipitation. Floods were, however, an annual event, and this cold snowmelt filled the shallow aquifers that bordered the channels. The release of this water during the summer and fall augmented and cooled base flows. The watershed was known to have been heavily timbered, and large woody debris recruited to the lower drainage from the forested banks of the upper forks. Scour around logjams and debris piles created and maintained numerous pools and gravel bars, both of which were used by spring chinook, coho and steelhead spawners. Water temperatures remained cool throughout the summer because side channels stabilized by the dense root systems of streambank willows, alder and cottonwood would have had a low width/depth ratio, would have been completely shaded except for beaver ponds, and would have received as base flow the cold spring runoff stored earlier. It was a system of this type that supported runs of spring chinook numbering in the thousands prior to development in the late 19th and early 20th centuries (Bryant and Parkhurst 1950).

The structure and character of the river has been completely changed because the river has been disconnected from its floodplain and the floodplain itself has been radically altered. In order to develop valley bottomland for agriculture, wet meadows were drained and side channels were filled. Whatever beaver survived the fur trade of the early 19th century were removed because of their tendency to build dams in or near irrigation ditches. Consolidated channels were diked to protect homes and fields. This diking and channelization had two main effects: it greatly reduced the frequency of spring floods and the degree to which shallow aquifers were recharged with cold spring run-off; and it accelerated flow, promoting down cutting and the further drying out of remaining wet meadows and wetlands.

Upland events have also had an impact. Logging in the Teanaway has a long history, and large log drives out of the Teanaway basin began in the late 19th century and continued until a railroad spur was installed in 1914. Splash dams were built near the mouths of the forks and dynamited during spring runoff to moved thousands of old-growth logs downriver to the Cascade mill in Yakima. These log drives swept away large woody debris, scoured the streambed, accelerated down cutting and lowered the riparian water table even more, retarding revegetation. More recently, clearcutting in the upper watershed has exacerbated a hydrograph that was naturally somewhat flashy, but had been tempered by a wide floodplain and many different kinds of hydraulic roughness. The current lack of large woody debris has allowed pools to be filled and gravel to be exported into the Yakima. The final straw in the modern destruction of the Teanaway River is the effects of irrigation withdrawals, which in dry years reduce base flows in the lower mainstem to levels that preclude adult spring chinook and coho access from August until such time as the falls rains come.

The destruction f the Teanaway has not, however, been complete. Although the river has been channelized and rip rapped where it approaches Highway 97, there are extensive reaches where the river and the highway are far apart; well over half of the mainstem is still anastomosing, even though the number of channels and interconnections is much lower than historically. A fairly extensive wet meadow/wetland complex still exists in the lowermost several miles of the mainstem, and this area has been identified as a critical piece of habitat and a top priority for preservation. Many mature cottonwoods still line the banks of the mainstem and the lower portions of the forks, but regular spring and winter-time floods have so widened the channel that the shade from these trees in the summer does not reach the remaining flow concentrated in the center of the channel. The Washington Department of Ecology has recently applied for and been granted funds to implement a riparian restoration project to attempt to reduce summer water temperatures. Several irrigation diversions in the lower five miles of the mainstem have, perhaps until recently, lowered instream flows to very low levels. The USBOR and BPA have, however, recently begun a piping and well pumping project intended to spare this critical last increment of instream flow. Threats of stranding or isolation to juveniles and impassibly low flows to returning adults will undoubtedly be eased by these measures. The mainstem, MF, NF, and WF are all included on the CWA 303(d) impaired water quality list for water temperature, with numerous excursions from state water quality standards noted in each area. Stafford Creek (tributary to MF Teanaway) is also on the CWA 303(d) impaired water quality list for water temperature.

The specific impacts on fish have been as follows. The extreme flashiness of the existing hydrograph (Figure 49) causes bed scouring and reduces survival of incubating eggs and overwintering juveniles. Another and more serious aspect of this flashiness is that peak runoff occurs about a month earlier and base flows are much lower (Figure 49). The extremely low base flows that occur now (the minimum mean daily flow over years 1994 – 200 ranges from 6 to 15 cfs) not only preclude adult access, but strand or isolate juveniles in small pools where they fall victim to predators and increase temperatures dramatically. July water temperatures over 70 ^{o}F have been observed in the lower North Fork (Todd Pearsons, WDFW, personal communication, 1998), and temperatures in the mid-70s have been observed in the lower mainstem in early September of 1998 (YN, unpublished data, 1998)

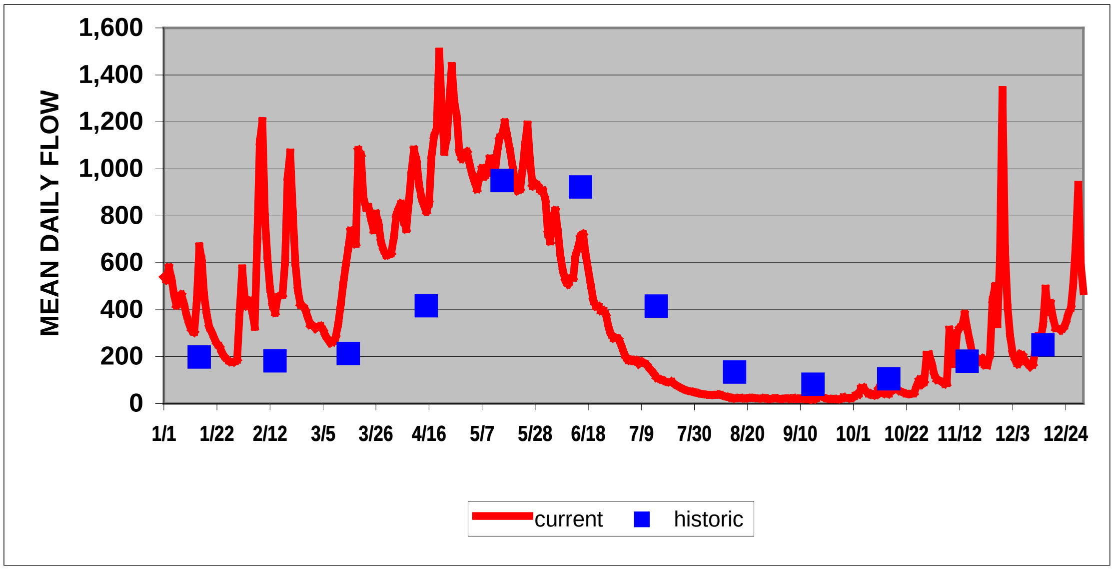


Figure 49. Current (1994-2000) and estimated historical hydrograph for the Teanaway River below the forks

Fig ? shows how the EDT simulation referred to earlier evaluated the impacts of specific environmental aspects of these changes on successive life stages of spring chinook. Non-normative flow clearly has the greatest adverse impact. The relative impacts of low habitat diversity, low channel stability, excessive temperature, entrainment or predation associated with irrigation withdrawals and sedimentation are, respectively, 75, 60, 50, 20 and 10% of the impact of flow. Not surprisingly, the specific life stages most affected by these impacts are adult holding and migration, subyearling rearing and incubation. The first three life stages are affected because they occur either in the summer of fall, when environment is at its worst, or they are particularly susceptible to channel instability.

Cle Elum River

The Cle Elum River is a left bank tributary to the upper Yakima River, entering at RM 185.6. The Cle Elum River, downstream of Cle Elum Dam, supports chinook, coho, steelhead, and bull trout, as well as a number of other salmonid and non-salmonid species (WDFW 1998). The lower Cle Elum River is a high-density chinook spawning area (WDFW 1998).

Upstream of Cle Elum Dam, the watershed supports kokanee and bull trout, as well as other resident salmonid and non-salmonid species. Kokanee and bull trout in this area spend their life in Cle Elum Reservoir, except for spawning and egg incubation to emergence. In its present condition, Cle Elum Dam (RM 8) is a complete fish passage barrier both to returning adults and outmigrating smolts. There are numerous side channels along the river below the dam. These side channels afford excellent rearing habitat for fry and parr in the spring and summer, but are dewatered during reservoir refilling in the winter, and probably represent severe stranding hazards at this time (WDFW 1998). Substrate condition is fair to good, with little sedimentation (WDFW 1998). The substrate is made of large materials, but there are adequate numbers of good gravel bars for spawning (CBSP 1990). The riparian corridor is in generally good condition (CBSP 1990, WDFW 1998). Water quality is good to excellent (CBSP 1990). Cle Elum River is on the CWA 303(d) impaired water quality list for water temperature, with numerous excursions from state water quality standards documented from the mouth to Cle Elum Lake in 1993. Thorp Creek, Cooper River, and Waptus River (all tributaries to Cle Elum River upstream of Cle Elum Lake) are on the CWA 303(d) impaired water quality list for water temperature.

The natural hydrology of the Cle Elum River is significantly altered by flip-flop. Instream flows are strictly regulated and are too high in the summer and too low in the winter. Winter flows range from 60% greater than optimal in October to 50% less than optimal in March (CBSP 1990)(this was for years just prior to 1990, is this still current). Spring and summer rearing is impaired by excessive flows during the irrigation season (May through early September), which range from 3 to 10 times optimal (CBSP 1990).

There are also adverse impacts associated with abrupt changes in instream flow (CBSP 1990). Sudden increases in flow cause fish to vacate feeding territories and migrate to new areas, increasing competition and stress, reducing growth, and increasing the likelihood of mortality, either through predation or being displaced to unsuitable downriver habitat (CSRP 1990). Sudden decreases in flow result in the stranding or death of salmonids that are unable to relocate to nearby pools or runs. Abrupt changes in flow in the Yakima Watershed are concentrated in reaches downstream of storage reservoirs and diversion dams, including the Yakima River between Keechelus and Easton dams, and the Cle Elum River downstream of the Cle Elum Dam (Mongillo and Falconer 1980, as cited in CBSP 1990).

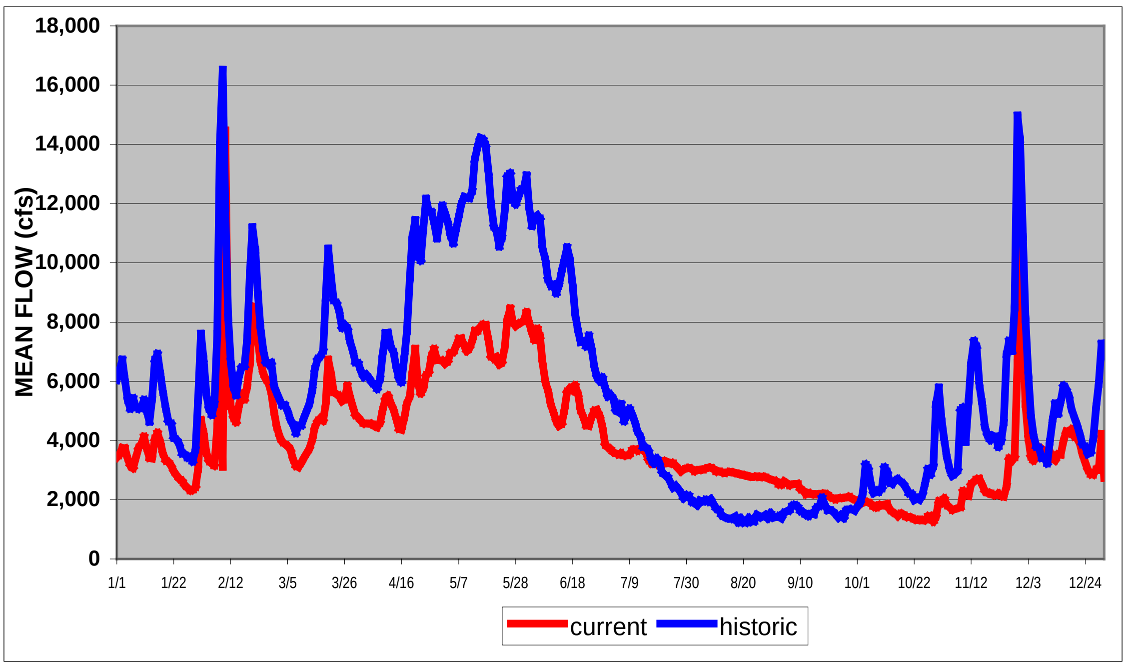
Middle Yakima

The relatively short section of the Yakima termed the middle Yakima has as its upstream border the Naches River confluence and its downstream border the Ahtanum Creek confluence. Wide Hollow Creek is the only tributary entering the Yakima inside the reach. It is bordered by the city of Yakima on its right bank and the community of Terrace Heights and pasture land on its left bank. It is singled out because it is the lowermost portion of the mainstem Yakima thermally suitable for year-round rearing of salmonids (Figure 51), because it lies just below the confluence of the Naches River and therefore receives all of the Naches' and upper Yakima's production of salmon and steelhead at one time or another, and because it was and to a degree still is a very complex and productive portion of the basin.

Historically, this alluvial reach included side channels that extended to the west well into what is now downtown Yakima and up to a mile to the east, in places being over two miles wide. It probably represented 8-9% of the anastomosing habitat present in the undeveloped basin. Like the reach above it, riparian vegetation consisted of patches of cottonwoods at varying stages of maturity, with dense thickets of willows in between. Log jams and debris piles would were common at channel bifurcations and along the high water line, and would have piled up large gravel bars and scoured deep holes. The lower portion of the reach was a zone of strong upwelling, containing numerous cool springbrooks. This area supported all life stages of all species of salmonid in the basin except sockeye. Its importance is reflected by the fact it was surrounded by three major Native American fisheries: Wah-Wa-Tam just below the present site of Sunnyside Dam, Oy-Yeh at the present site of Wapato Dam (Splawn 1942), and a site on the lower Naches near the Yakima confluence General William McClellan described in his journals during an expedition through the Yakima Valley in 1853 (Glauert and Kuns 1976).

Riprapped dikes now narrow most of the reach on both banks, and all of the right-bank side channels that used to flow through the city of Yakima have been filled. Large woody debris is scarce, both because of historical log drives and because of the very high velocities present in the remaining channels from March through September. Mean monthly water velocities across a number of PHABSIM transects (USFWS 1989) average 7.5 fps

(6.1 to 8.5 fps range) from March through September, and two-foot standing waves are present in several of the remaining side channels during this period. Indeed, these high velocities and the few remaining log jams have frequently made the reach too hazardous for juvenile distribution studies in the spring and summer. The velocities that characterize this reach in the spring and summer are much higher than desired for steelhead rearing (WDFW 1998, CBSP 1990), especially during the emergence period of June and July. The riparian buffer in the urbanized areas of this reach is minimal (WDFW 1998), as most of the right bank bordering the city of Yakima consists of a massive, riprapped dike. Overgrazing has severely degraded riparian vegetation along a substantial fraction of the left bank as well (CBSP 1990). Substrate is mostly cobble and large gravel, with some boulders, sand, and silt (WDFW 1998). Interstate 82 has isolated a number of large and potentially productive springbrooks in the lower end of the reach, which the Yakama Nation is attempting to reconnect.



USBOR Hydromet data

Figure 50. Regulated ("current") and estimated unregulated ("historic") mean daily flows, Yakima River at Terrace Heights, 1994-1999

Return flows from the Roza Power Plant attract adult salmon homing to the upper Yakima, and can delay their spawning migration significantly. The canal is screened at its mouth (RM 113.3) but still discharges upper Yakima water and therefore induces salmon homing on the odor of upper Yakima water to remain in the vicinity. From October through December of 2000, several hundred salmon, primarily coho, were observed holding below the power canal outfall. Neither shutting off power generation for a number of days nor seining fish out of the pool below the outfall was successful in preventing coho salmon adults from returning to and holding in this area. Ultimately, the Yakama Nation seined the pool again and collected 80 coho adults to use as broodstock for their coho re-introduction program (Dunnigan 2001).

Notwithstanding what has been lost, the reach still contains many side-channels, islands and back water areas. Hatchery-reared coho salmon spawn here and in Wide Hollow

Creek (Dunnigan 2001), as do steelhead (Hockersmith et al. 1995). Sporadic observations indicate that juvenile spring chinook and rainbow/steelhead rear in the slower areas. Unfortunately, these areas also support two significant predators, Northern pikeminnow and smallmouth bass (YN, unpublished data; Erik Anderson, WDFW, personal communication, 1999), as well as redside shiners, a known competitor for space and food (Patten and Thompson 1970). As shown in Figure 50, flows are from 1,000-2,000 cfs lower than normative after irrigation season, a circumstance causing some of the remaining side channels to dry up (D. Eitemiller, CWU, personal communication, 2000). Temperatures, however, are moderate year-round (Figure 51), a fact probably attributable to a relatively intact hyporheic system and the extensive zone of upwelling in the lower portion of the reach (Sanford 2001).

This reach has been identified by the latest EDT analysis and by the Reaches Study as having extremely high restoration potential and preservation value, both for spring chinook and steelhead.

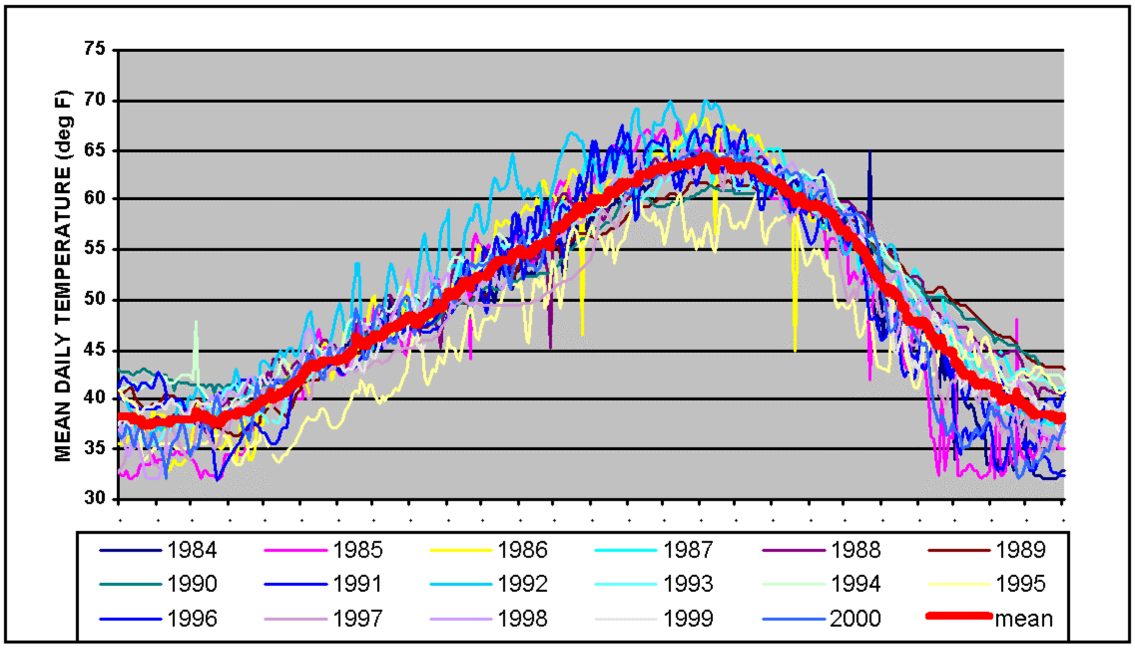


Figure 51. Mean daily water temperature at Parker, a site several miles below Ahtanum Creek, 1984-2000

Lower Yakima

The lower Yakima has been defined as the Yakima mainstem from the confluence of Ahtanum Creek at RM 106.9 to the confluence with the Columbia as well as Marion Drain (RM 82.6). This reach has been set apart because it is environmentally distinct from the rest of the basin in terms of water quality, hydrograph, predation, competition, the diversity and abundance of exotic fish species, impacts associated with diversion dams and, perhaps most importantly, because of excessive summertime water temperatures. At the present time, summer water temperature overrides all other aspects of the aquatic environment at least for the lower two thirds of the reach. Directly or indirectly, excessive summertime water temperatures in the lower Yakima preclude self-sustaining populations of any salmonid with a resident[11] freshwater life history extending into or beyond July. This constraint excludes

[11] "Resident" is used here in the sense of rearing withing the subbasin and usually relatively near the natal area.

all trout and salmon with the single exception of fall chinook, which usually smolt and exit the lower river before temperatures become prohibitive. A significant implication of the temperature regime in the lower Yakima is that subyearling or yearling steelhead parr, displaced from the lower Naches and middle Yakima by flip-flop, are probably doomed.

Reminiscent of the pattern in the upper Yakima, the reach consists of two unconfined and mostly alluvial reaches separated by two confined sections. Except for a short (~2-mile) and largely inundated delta section, the lower 8 miles of the Yakima River is confined and flows through the heart of the Tri-Cities (Richland, Kennewick and Pasco). From the West Richland Bridge at RM 8.0 to Horn Rapids Dam at RM 16, the river is naturally unconfined, alluvial, and had an anastomosing channel morphology in historical times. From Horn Rapids Dam to the Euclid Rd Bridge at RM 55, the river is confined in a shallow canyon, the gentle slopes of which consist of sagebrush desert or irrigated hop fields and vineyards. The remaining 52 miles of the reach is unconfined, and is divided roughly equally into a meandering half and an anastomosing half. The meandering section extends from RM 55 to a point roughly midway between the confluences of Satus and Toppenish Creeks (~RM 75), and consists of an extremely low gradient (0.1%), deep and slow-moving single channel bordered by oxbow lakes, sloughs and wetlands. The uppermost ~32 miles of the reach, roughly centered around the city of Wapato, is the largest anastomosing alluvial section in the entire Yakima Basin. Two of three major lower Yakima tributaries, Ahtanum and Toppenish Creeks, flow into this Wapato alluvial reach ("Wapato reach") and the third, Satus Creek, enters the Yakima just below it. Several other streams entering the lower Yakima are noteworthy because they have been transformed into irrigation drains and/or wasteways, and discharge large quantities of suspended sediments and have delayed the spawning migration of adult chinook and coho homing on the olfactory cues of upper Yakima River water. These streams are Granger Drain, Sulphur Creek, Snipes Creek and Corral Canyon Creek. Of the four, Snipes and Corral Canyon Creeks most nearly approximate a natural stream; Sulphur Creek has been channelized into a deep, straight, riprapped ditch, and Granger Drain is an entirely artificial ditch built for drainage of irrigated fields.

Historically the two alluvial portions of the lower Yakima supported all life stages of summer chinook, fall chinook, steelhead and coho, as well as the juvenile life stages of spring chinook. The importance of the Wapato alluvial reach to historical production was probably enormous. As is evident in Fig ?, the Wapato alluvial reach was about 30 miles long, up to five miles wide and extraordinarily complex. Except for channels in recently disturbed areas, most would have been bordered by dense growths of willows and the larger, older channels by cottonwoods. The accumulation of woody debris, recruited on site and from the upper basin, must have been enormous and was probably a major reason for the channel complexity in the first place. The benefits of large woody debris with respect to creation and maintenance of pools and gravel beds would have created ideal structural conditions for spawning and prespawning adults, and the discharge of spring runoff stored in the Toppenish/Yakima hyporheic aquifer and in various wetlands along Toppenish and Simcoe Creeks would have kept water temperature cool enough for juvenile rearing in the summer. A major proportion of the basin-wide production of chinook and coho salmon was probably attributable to this reach and, to a much lesser degree, its diminutive sister reach between RM 8 and 16. One significant difference between the Wapato and the lower alluvial reach is that the latter was not fringed by cottonwoods. Early explorers noted cottonwoods were not encountered below ~RM 40 (except in the Yakima delta), although willows and other brush was dense (Harner 2001).

The structure and characteristics of the two alluvial reaches have been so changed over the past 150 years as to destroy their benefit to all but a limited number of life stages for a limited number of species. Almost the whole of the Wapato alluvial reach ("Wapato reach") is now bisected and confined on the left bank by riprapped revetments along Interstate 82, and the right bank has been radically narrowed by earthen dikes as well. Where formerly hundreds of channels sprawled over miles, now one to three flow within a floodway of several hundred meters to half a mile. All of the historical side channels along the right bank have been filled in or, like Wanity Slough, converted into irrigation ditches. The meander reach, unlike most other portions of the lower Yakima, has not been severely hemmed in by dikes, and flooding of agricultural lands and the Satus Wildlife Preserve is not infrequent. Unfortunately the meander reach is also characterized by extensive stream bank erosion, caused by streamside tillage and grazing. Large woody debris is lacking throughout the lower Yakima, although a considerable number of debris piles lodged in the upper portion of the Wapato alluvial reach after the 1996 flood.

The Wapato reach, along with the meander reach, is still the major winter holding area for steelhead pre-spawners, and the entire lower Yakima is still a major overwintering site for juvenile spring chinook and steelhead, and is in the process of becoming one for the new, naturalized coho population (Fast et al. 1991; S. Croci, USFWS, USBOR Workshop, 2001). Part of the attractiveness of the lower river for overwintering salmonids is doubtless attributable to the large influx of warm ground water recharged annually by irrigation. Coho spawn in the Wapato reach now, as they did historically. They also spawn in many of the smaller tributaries and ditches, probably as a result of false attraction to upper Yakima River water discharged into these creeks and drains. Flooding has been virtually eliminated in the Wapato reach except during very large events, and this factor, as well as others acting both within and upstream of the reach, has resulted in prohibitively high summertime temperatures.

All of the impacts described for the Wapato reach apply as well to the lower alluvial reach between RM 8 and 16, only more intensely. Except for a few wide, short braids, all the lateral channels have been disconnected, filled and converted to pasture or residential property. Of all the alluvial reaches in the Basin, this one has been the most thorough transformed by development. Because this was the last alluvial reach in the Yakima River, it was probably an important nursery area for lower river fry.

The Yakima River delta has also been radically altered. Prior to development and certainly prior to construction of McNary Dam on the Columbia River, the floodplain of the delta was extensive and complex. Remnant riparian forests remain on exposed portions of the extensive alluvial delta (most of the original delta is submerged). The reach is substantially modified by inundation and erosion associated with McNary Pool, but a substantial expanse of wetlands exists on the fringes. Impoundment by McNary Dam extends about 2 miles up the Yakima River channel, further modifying the flood plain system. Surface and groundwater interactions appear to be dominated by infiltration of McNary water, which probably maintains the fringing wetlands. The Yakima River confluence reach is best described now as an essentially lotic environment. The McNary pool backwater eliminates discernable current in the channel, which is several hundred yards wide. The mouth has been channelized and enters the Columbia as a single channel. Large woody debris is removed for navigation purposes and the substrate is comprised of fine sediments which drop out in this low velocity region. There are a number of "cul de sacs" in the area that are known to contain large numbers of smallmouth bass, and channel catfish are quite numerous in the main channel. The lack of instream cover, low water velocities, high water temperatures and dead-end "bays" all suggest this may be a region of especially high predation.

Water quality.

Temperature is the most serious of a number of serious water quality problems in the lower Yakima. Lilga (2000) found that temperatures in the lower river from June through November, 1998 were lethal (>15.6 C) for salmon egg and fry incubation between 60 and 85 percent of the time, that temperatures are stressful for juveniles (>18.3 C) between 25 and 65 percent of the time, and were stressful for adults (>15.6 C) between 60 and 85 percent of the time. Using Hydromet data and the criteria of 21.1^{o}C (70 ^{o}F) and 25^{o}C (77 ^{o}F) for avoidance and upper incipient lethal temperatures, respectively, for chinook juveniles, the Yakama Nation determined the proportion of the time water temperatures equaled or exceeded avoidance and lethal levels at Prosser. Over the period 1982 – 2000, avoidance temperatures were reached in the months of May, June July, August and September an average of 0.7, 15.1, 54.4, 55.4 and 4.3%, respectively. For the same time period and months, lethal temperatures were reached 0, 1.7, 5.6, 3.0 and 0% of the time. It should be noted that these are average figures over all 19 years. Conditions are considerably worse in individual, hotter years. The hottest years in recent memory were 1992 and 1994. Over the last 10 days of June, 1992, Prosser water temperatures averaged 25.8^{o}C (78.4^{o}F), and in July, 1992, were above 21.1 and 25^{o}C 100% and 23% of the time, respectively. Mean daily Prosser water temperature exceeded 21.1 and 25^{o}C in July of 1994 94% and 55% of the time, respectively. It should be pointed out that temperatures need not exceed upper incipient lethal to cause significant mortality to juvenile salmonids. Such stressful temperatures dramatically increase the incidence and morbidity of infectious diseases (wild Yakima spring chinook are known carriers of BKD and Ceratomyxa) and increase losses to piscivorous fish both by debilitating the prey and increasing the feeding rates of predators (Dunnigan 2001). Finally, water temperatures are generally 1 to 5^{o}C higher in the lowermost sections of the Yakima than they are at Prosser Dam (Mark Johnston, YN, personal communication, 1992).

Conditions are not, however, without some redeeming features. There is, for one thing, an increasing thermal gradient from the upstream to the downstream boundaries of this reach. Figure 52 depicts mean daily water temperature along this gradient through the smolt outmigration season for the years 1988 through 1993[12]. Note that the six-year mean temperature at Richland approaches upper incipient lethal by mid June. By contrast, mean water temperatures just below Sunnyside Dam are just slightly above optimal. There is therefore a zone of "thermal habitability" at the upper end of the reach that probably varies in size from year to year. Moreover, an analysis of the lower basin in August, 1997, using digital aerial thermography, indicated that there are numerous sources of cooler water entering the system from spring brooks and some tributaries (Holroyd 1998). This influx of cooler ground water likely provides thermal refugia for juvenile salmonids - and was almost certainly much more pronounced historically when annual spring floods filled enormous hyporheic aquifers. Finally, high water temperatures are not nearly so serious a problem in Marion Drain as they are in most portions of the lower Yakima. As shown in Figure 53, temperatures in Marion Drain are about 6^{o}C cooler in the summer and 5^{o}C warmer in the

---

[12] Note that West Richland (RM 8.0) temperatures are not continuously monitored. The West Richland data in this Fig were estimated from a regression on 1992 data in which West Richland temperature is a function of mean daily water temperature at Prosser and maximum daily air temperature at the weather station in Hanford, WA. It is noteworthy that this regression indicates water temperatures will exceed 25^{o}C whenever the mean daily temperature at Prosser equals or exceeds 21^{o}C and the maximum air temperature at Hanford equals or exceeds 32.2^{o}C (90^{o}F).

winter than temperatures in the mainstem. This thermal moderation is attributable to the large proportion of groundwater in the drain.

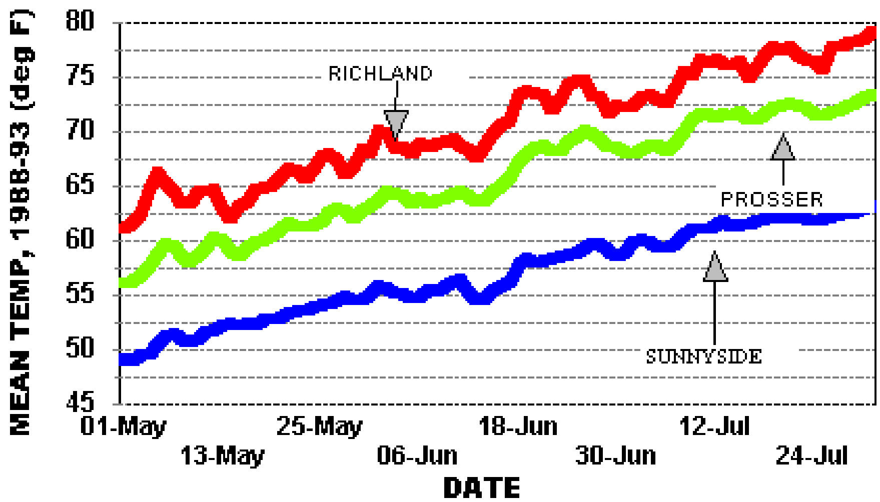


Figure 52. Mean water temperatures through outmigration season at Sunnyside, Prosser & Richland, 1988-93.

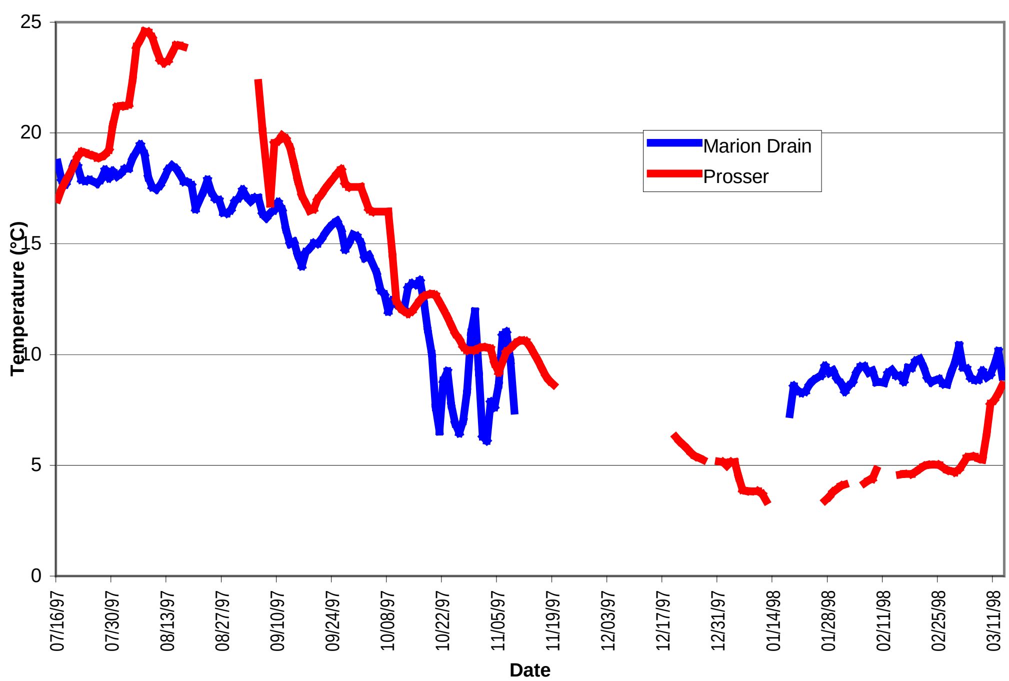


Figure 53. Mean daily water temperatures in Chandler Canal and in the Yakima River at Prosser, July 1997 through March 1998.

Other water quality problems in the reach include inadequate dissolved oxygen concentrations, excessive pH, excessive nitrite/nitrate and phosphorous concentrations, pesticide concentrations among the highest in the United States, fecal coliform concentrations, heavy metals, instream flow and turbidity. The lower Yakima River and seasonal streams in the vicinity of Richland suffer from many of the problems associated with urban streams; leaking septics, storm sewer pollution, and agricultural runoff (WDFW 1998). Numerous excursions from state water quality standards are documented in the lower Yakima River. Various lower Yakima reaches are included on the CWA 303(d) impaired water quality list for problems including: 4,4'-DDD, 4,4'-DDE, Arsenic, DDT, Dieldrin, dissolved oxygen, Endosulfan, fecal coliform, Mercury, PCB-1254, PCB-1260, pH, Silver, instream flow, temperature, and turbidity.

The chemical water quality problems in the lower Yakima are the result of the fact that most of the water in the lower river during irrigation season consists of irrigation return flows. While return flows comprise about 5 percent of the yearly Yakima River flows in the reach from Sunnyside Dam to Wilson Creek, below Sunnyside Dam this percent increases to more than 30 percent on an annual basis, and to more than 80 percent in the summer months (Anonymous 1974). Soluble contaminants dissolve in untranspired irrigation water, and insoluble contaminants adhere to soil particles which are carried along with the return flows.

There is no single cause or strongly dominant factor contributing to the thermal pollution in the lower Yakima. Rather, the net result of all of the major deviations from normative conditions throughout the basin have made a contribution. Riparian degradation and intensive logging, channel simplification, elimination of wetlands, floodplain disconnection, water withdrawals and the elimination of annual spring flooding all play a role. Each either increases the caloric loading of the lower river or reduces the quantity of cool groundwater that can be discharged back to the river as base flow. Although Lilga (2000) and Vaccaro (1986) concluded that a simple increase in streamflow would not substantially decrease summertime water temperatures in the lower river, they did not examine the effect of very low flows in the mainstem below Prosser Dam. Stanford (USBR workshop, May 2000) reported that flows below about 300 cfs exposed boulders in this reach, which when fully heated by direct sunlight had the ability to increase water temperature by several degrees centigrade in a matter of a few miles. There may, therefore, be a threshold effect of flows in that flows below some threshold value expose a large area of rock which further heats the river by conduction.

The solution to the temperature problem in the lower Yakima is clearly to attempt to restore as many elements of the normative environment as possible. An idea that has surfaced in recent years entails an attempt to recreate at least some of the hydrological and thermal conditions associated with historical spring floods. Specifically, several YN researchers have wondered whether running water through one or more of the lower Yakima irrigation systems during mid-winter might not recharge aquifers with very cold water that could augment and cool baseflows to some degree, perhaps providing a series of thermal refugia along the lower river. The YN is currently involved in the initial stages of investigating the feasibility of such a project.

Sediment loading is another major water quality problem in the lower Yakima. Although never measured, the quantity of fines in mainstem spawning areas is sufficient in many areas to fully embed the substrate and is clearly sufficient to limit carrying capacity and productivity. The meander reach probably acts as a settling basin, sparing the fall chinook spawning areas between Benton City and Horn Rapids Dam the worst impact of the worst irrigation drains; it is in any case silt-bottomed and totally unsuitable for spawning. The proportion of fines in Marion Drain substrate is in the neighborhood of 30% (Hallowed 1984). The impact of this sediment on incubating fall chinook eggs in the drain is much less than it would be in the mainstem, because redds are cleaned during spawning and are not "re-silted" by winter floods (the drain receives only ground water after irrigation season).

Joy and Patterson (1997) constructed a sediment budget for the lower Yakima in 1995. Over the full irrigation season (March – October) 67% of the 574 tons/day of suspended sediment entering the reach originated within the reach. However, during the peak of the irrigation season (July-October), 92% of the 354 tons/day suspended sediment load originated within the reach. Of the sediment sources within the reach, Sulphur Creek, Granger Drain, Moxee Drain and Snipes Creek contributed 55% of the sediment, while drains flowing off Yakama Reservation lands, ungaged smaller drains and unknown sources contributed 19, 11 and 14% of the total. It was estimated that 153 tons/day -- 43% of the total suspended sediment load -- was deposited within the reach during the July-October period.

Progress in reducing sediment loading in the lower river has, however, been made in recent years. Sulphur Creek, Granger Drain, Moxee Drain and Snipes Creek receive irrigation drain water and/or operational spills from the Roza and Sunnyside Canals and from irrigators within their districts. The Roza-Sunnyside Board of Joint Control set a goal in 1995 of bringing irrigation return flows into compliance with current state water quality standards and recent Total Maximum Daily Load (TMDL) goals for the lower Yakima set by the Department of Ecology. The goal adopted was a turbidity value of 25 NTU or less for all project waterways. The year 2002 was set as the date for attaining compliance and provisions were made to enforce better management practices on water users within the districts. By the 2000 irrigation season, significant progress had been made. Total suspended solid loading from Granger Drain was more than halved from the 1995 values reported by Joy and Patterson, and loading from Sulphur Creek has decreased by about a third (USBR 2000).

Access

Except for Marion Drain fall chinook, adult access is not generally a problem in the lower Yakima. Occasionally, high September temperatures in the lowermost reaches probably delay the entry of steelhead spawners, and low flows below Sunnyside Dam in drought years might delay migrating spring chinook, although Hockersmith et al (1995) found no significant delay among the radiotagged spring chinook they tracked in 1992 (a very low flow year). A problem does, however, exist on the 1.5 miles of Marion Drain below the tainer gates at the Highway 97 crossing. The drain below the tainer gates is quite broad and shallow and, except for a fringe of Russian olives and brush along the banks, provides virtually no cover for migrating adult salmon. It appears as though adult fall chinook are reluctant to enter the lower drain until, fortuitously, the tainer gates are abruptly opened in mid-October at the end of irrigation season. The water impounded above the tainer gate is suddenly discharged increasing depth and dramatically increasing the turbidity of the water entering the Yakima. Seiler (1992) found that fall chinook movement commenced immediately after the gates were opened, and was minimal both before the opening and after the impounded water had drained away.

Substrate

Except for the meander reach, Marion Drain, the 17-mile reach between Prosser Dam and the Benton City Bridge (RM 29.8), and the delta area, substrate consists of embedded large cobble and gravel. The predominant substrate in Marion Drain is small gravel, with a high proportion of silt and other fine material. Substrate in the meander reach consists of deep mud and sand, as it does in the delta. The Prosser-to-Benton-City has substrate consisting largely of very large boulders and sand, with bars of embedded cobble/gravel associated with islands.

Riparian Conditions

The historical riparian communities along the lower Yakima are still generally recognizable. As was true before development, trees are scarce below Prosser Dam, although Russian olives have invaded some areas and silver maple has invaded the lower confined reach. Mature cottonwoods and an understory of willows and other brushy plants form an almost unbroken corridor from Prosser Dam to Sunnyside Dam, except where prohibited by highway revetments or levees.

Ecological Interactions

Qualitative examination of fish distribution indicates that the presence and abundance of exotic species declines upstream (Table 3) (Geoff McMichael, pers. comm.). For example, near the confluence of the Yakima and Columbia Rivers, ten exotic species are found in relatively high abundance and three species are rarely encountered; whereas from Roza to Keechelus Dams, there are seven exotic species that are rarely encountered. This pattern is likely a function of the following: (1) proximity to the Columbia River—a source pool of potential colonists, and (2) downstream accumulation of various anthropogenic impacts. the downstream cumulation of anthropogenic impacts are manifest by: (1) altered flow regime, (2) presence of numerous irrigation dams that provide slack water habitat for predatory fish and which likely disorient and concentrate outmigrating salmonid and steelhead smolts and parr, and (3) elevated stream temperatures. Indeed, high concentrations of predatory fish have been observed below Sunnyside, Wapato and Prosser Dams during smolt outmigration (McMichael et al. 1998a, 1998b).

A study was initiated in 1997 to examine the impact of piscivorous fish on the survival of outmigrating smolts in the lower Yakima River (McMichael et al. 1998a). [A sister study on piscivorous birds was also initiated in 1997, and showed the potential for significant lower Yakima impacts in the vicinity of diversion dams and diversion dam outfalls. The results and implications of this study will be discussed below along with other dam-specific factors.] Results indicated that predation rates were unnaturally high and were caused mainly by three predators; the indigenous northern pikeminnow *(Ptychocheilus oregonensi*s), found primarily above Prosser Dam, and two exotic piscivorous species, the smallmouth bass *(Micropterus dolomieu*i), found primarily below Prosser Dam, and perhaps the channel catfish *(Ictalurus punctatu*s), found primarily in and just above the Yakima River delta.

Specific findings for the years 1998-2000 for smallmouth bass were as follows. Estimated abundance of smallmouth bass of piscivorous size increases from late March to a peak in late May. Most of this increase is due to immigration from the Columbia of pre-spawning adults. Peak abundance estimates for the lower Yakima from Prosser Dam to the mouth were about 40,000, 35,400 and 27,400 in 1998-2000, respectively. Consumption rates, expressed as the proportion of bass with an identifiable salmonid or salmonid bone in the gut, peaked in late May in all years, at about the peak of the fall chinook outmigration, at around 30%. These abundance and consumption rates are substantially higher than values reported for other Pacific Northwest systems, and are attributed to relatively high temperatures that lead to physiologically faster digestion rates (and subsequently increased predation rates) and the presence of irrigation dams and a modified flow regime -- modifications to the natural habitat template that tend to select for nonnative species.

Fall chinook and to a lesser degree mountain whitefish were the preferred fish prey in all years, accounting for roughly 70% of all fish consumed. Summing the products of weekly abundances and consumption rates, it was estimated that smallmouth bass consumed 442,000 salmonids in 1998 and 171,000 in 1999, most of which were fall chinook smolts (estimated spring chinook consumption in 1998 and 1999 was 2,326 and 3,758, respectively). Total salmonid consumption has not yet been estimated for 2000, but water temperatures were higher in 2000 than 1999: mean May temperature in 1999 and 2000 were 56.2 and 59.3 ^{o}F, respectively; mean June temperatures in 1999 and 2000 were 59.4 and 64.5 ^{o}F. Therefore, the higher temperatures and therefore consumption rates of 2000 might cancel the lesser abundance, such that total salmonid consumption in 2000 might be roughly equal to the 171,000 estimated for 1999. Adjusting total Chandler fall chinook smolt counts for the relative production occurring above and below the trap, roughly 14 and 49% of the total fall chinook smolt production of the entire basin might have been consumed by bass in 1999 and 2000. If the 2000 consumption estimate is approximately 171,000 as it was in 1999, 13% of the production would have been taken (Pearsons 2000).

Findings to date for Northern pikeminnow have been somewhat compromised by the low catchability of fish in 1998, and to a lesser degree in 1999. Low recapture rates of marked fish led to unreliable abundance estimates in 1998. In 1999, total abundance of Northern pikeminnow in the middle and lower Yakima from Roza Dam to Prosser Dam varied from 43,163 in May to 71,155 in April. Unlike bass, Yakima pikeminnow appear to be resident fish, as 95% of the recaptures of marked fish occurred within the original capture and release site. Over the three years of the study, it has become clear that the bulk of the Yakima pikeminnow diet consists of crayfish and other invertebrates (31%) and fish (25%). Consumption rates of salmonid fish increased through the season, but peaked at the relatively low rate of 4.1% averaged over all three study sites in 1999. There was, however, one significant exception to this generalization: consumption rates in the study site below Sunnyside Dam peaked at 29% in mid May, and pikeminnow abundances were 2-4 times greater in this site than the other two as well. The other two sites were in the open river near Granger and Toppenish. The lower abundances and consumption rates there may simply reflect the tendency of pikeminnow to congregate below bypass outfalls and to prey on disoriented smolts re-entering the river. Unlike bass, pikeminnow readily consume spring chinook smolts. In 1998, about half of the Oncorhynchids consumed were yearlings, but in 1999, virtually all were. Total consumption of Oncorhynchid yearling smolts in 1999 was estimated at 60,583, or about 4% of all yearling smolts estimated to have been migrating through the system. Unfortunately, this figure cannot be completely disaggregated between spring chinook and coho because no diagnostic bones exist to make this distinction. Nevertheless, based on the dates of a major release of hatchery coho and the total number of yearlings consumed by that time, it was estimated that at least 33,400 spring chinook smolts were taken. The 2000 data has not been totally analyzed, but preliminary abundance estimates are in the neighborhood of three times the average for 1999. Moreover, water temperatures were somewhat higher in 2000 than 1999. It would therefore not be unreasonable to assume total yearling smolt consumption would also be roughly three times as great -- ~182,000 and perhaps 12% of all yearling migrants (Dunnigan 2000).

A final point about the bass and pikeminnow predation studies: the impact of bass and pikeminnow on Yakima smolt production has almost certainly been underestimated thus far. Spring water temperatures in the lower Yakima in 1998 and 1999 were generally 1-3^{o}C lower during May than the 10-year average, and flows in 1998 and 1999 were more than twice as great as the 10-year average for most of the month of May.

Because of low catchability, reliable abundance estimates for channel catfish have never been generated. Moreover, catfish are so omnivorous and plastic in their diet, that their status as a significant smolt predator is uncertain. Moreover, only 2.9% of the sampled catfish had consumed salmonids in 1999 and only 4.2% in 2000.

Removal by trapping and electrofishing, relocation, removal of angling regulations, bounty implementation and decreasing water temperatures by 2^{o}C have all been proposed as methods of limiting the impact of bass and pikeminnow predation. McMichael et al. (1999) contend a decrease in May water temperatures, if feasible, would represent the most satisfactory solution. They point out that a 2^{o}C decrease in water temperature would decrease digestion rates, which in turn would reduce predation rates of smallmouth bass by 23% in the river between Benton City and Chandler powerhouse. They also suggest that a combination of management solutions be implemented, after weighing potential risks to non-target fish species. Stanford (2000) points out that normative flow might be the solution to much of the nonnative fish problem. Many problematic nonnatives are sensitive to scouring floods, having evolved in much more benign conditions. Stanford reviewed the effects of scouring floods on many of these fishes and concluded that that scouring flows depress populations of nonnatives and enhance natives in alluvial rivers of Western USA. Li et al. (1987) documented this phenomenon for a variety of rivers in the Pacific Northwest (not the Yakima, however).

Hydrograph: general impacts

Figs 54 and 55 depict current and historic flows just below Sunnyside Dam and at Kiona (RM29.9) – a point low enough in the river to represent flows at the mouth. The changes made to the normative hydrograph are similar to those seen elsewhere in the basin with one major exception: current flows are always lower than historical flows.

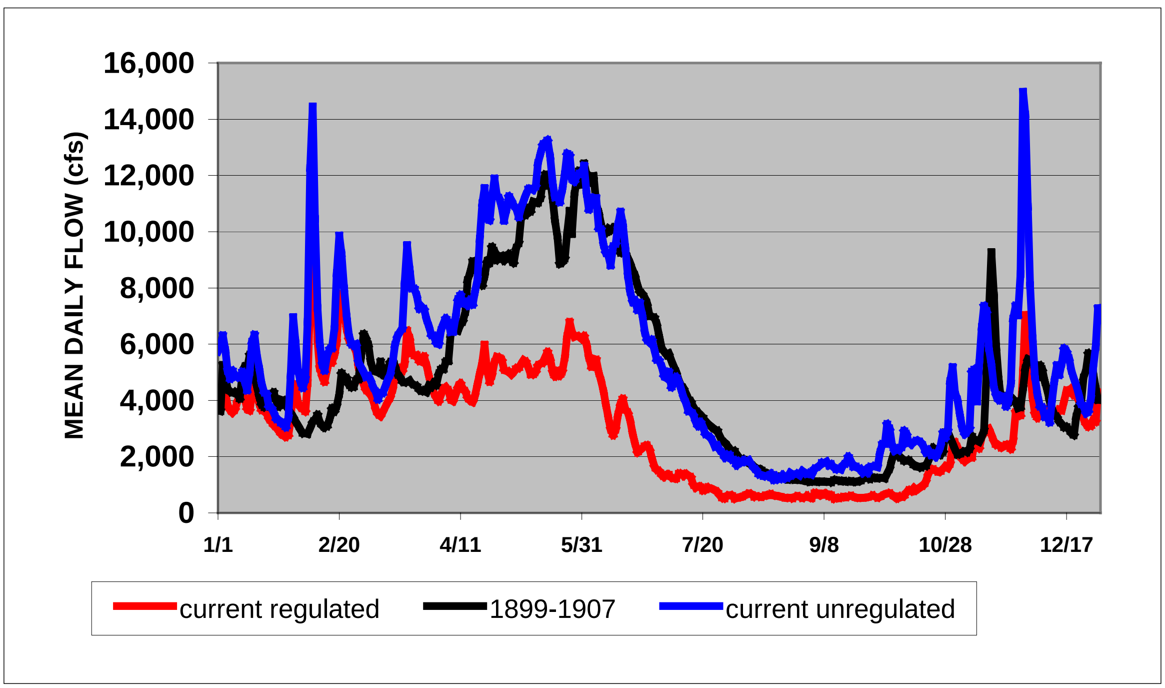


Figure 54. Mean daily regulated and estimate unregulated flow averaged over the period 1994-2000, Yakima River immediately below Sunnyside Dam, and mean daily unregulated flow averaged over the period 1899 – 1907 at the same site (USBOR Hydromet data and USGS historical data).

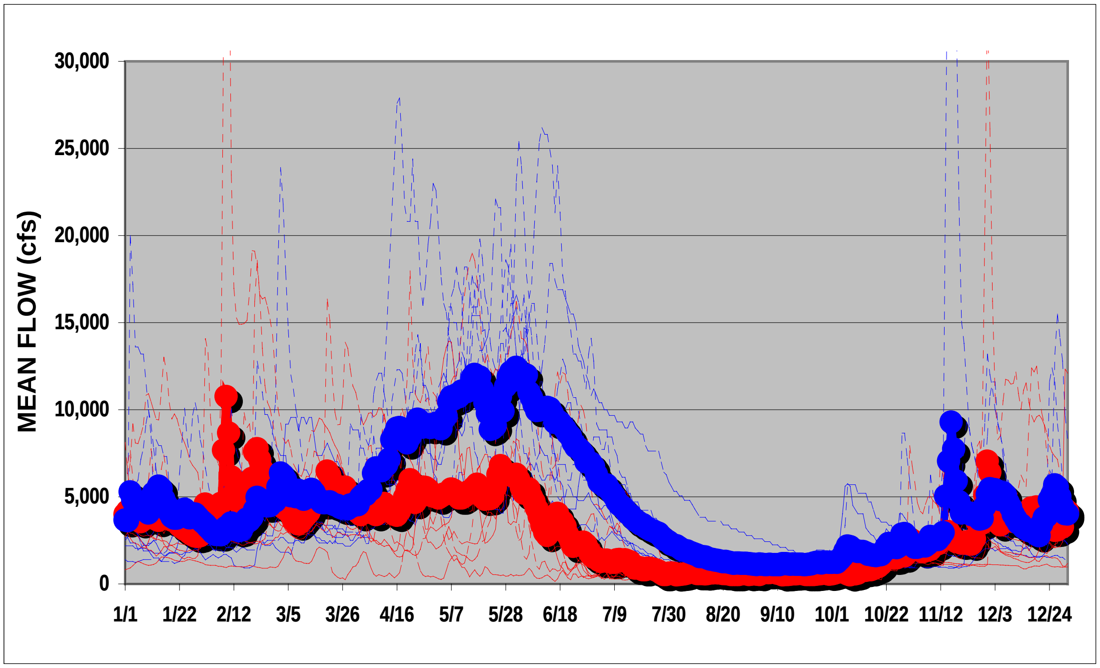
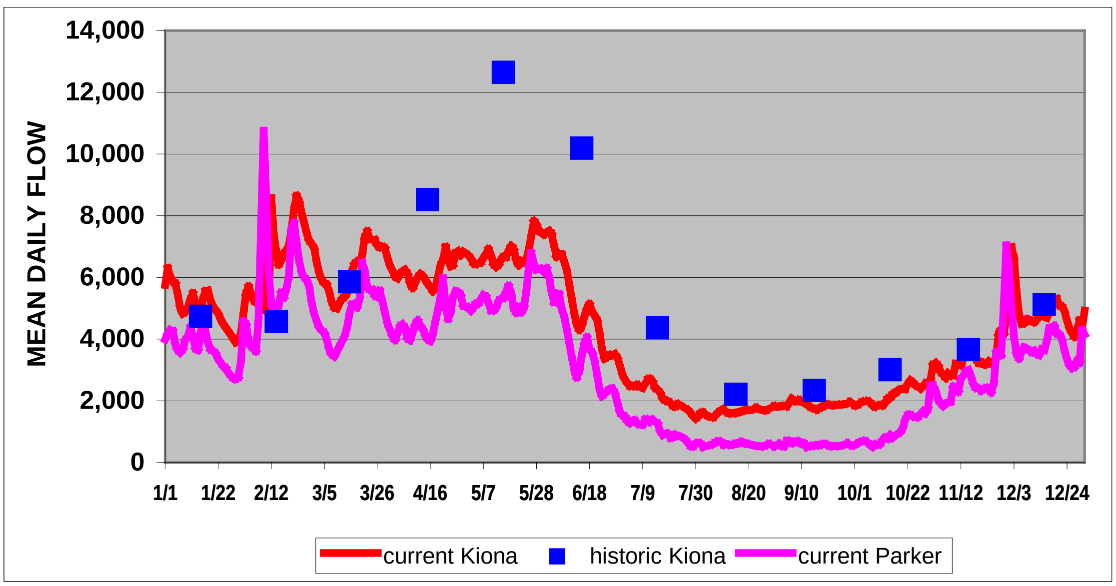


Figure 55. Mean daily flow, Yakima River immediately below Sunnyside Dam, for the period 1899-1907 (blue lines) and 1994-2000 (red lines). Mean daily flows within individual years are also shown as light dashed lines



USBOR Hydromet data and HKM Engineering 1990

Figure 56. Mean daily regulated flow at Parker (RM 103) and Kiona (RM 29.9) averaged over the period 1994-2000 and estimated mean monthly historical flows at Kiona

The spring freshet is more than halved, and winter flows are subnormative, as seen in the upper and middle Yakima; but late spring and summer flows are also considerably sub-normative. Lesser discharge implies lesser rearing area, especially in a relatively unconfined reach as the upper Wapato alluvial reach, with its many side channels and floodways. The impact of this flow-mediated reduction in habitat area is disproportionately large, because the side channels and grassy floodways that are no longer inundated during the spring are ideal rearing areas for fall chinook fry. Figure 54 includes actual mean daily flow estimates from the period 1899 through 1907 (black line), a period when the basin was largely unregulated. It is interesting to note that the Bureau of Reclamation's estimate of mean unregulated flows for the years 1994 – 2000 very closely matches actual unregulated flows at the site.

Figure 55 plots average of mean daily flows below Sunnyside Dam over the years 1994-2000 (red lines) along with the corresponding average for the years 1899-1907 (blue lines). Included in this plot are mean daily flows for individual years – dashed red lines for 1994-2000 and dashed blue for 1899-1907. While a difference in overall variability of flow about the mean is not apparent in this plot, it is apparent that current flows are much more likely to fall substantially below the mean during the smolt outmigration period of March through June. The tendency for flows to fall during the spring has implications for smolt outmigration, as spring chinook movements are strongly and positively correlated with positive flow acceleration (Mundy and Watson unpublished data 1996), and survival through the lower river is positively associated with discharge (see next section).

Flow fluctuations generated upstream become a significant percentage of the base flow below the Sunnyside Diversion Dam. Before 1995, the Bureau of Reclamation and local fisheries managers had a non-binding agreement that flow should not be allowed to fall below 200 cfs below Sunnyside Dam. Unfortunately, the precision with which river flows at this point can be managed is not great, and "water holes" – periods in which flows fell below 200 cfs – were relatively frequent during dry years. Instream flows fell below 200 cfs 155 time over the period 1982-1994, but were particularly frequent during the drought years of 1986 – 1989. The number of times mean daily flow below Sunnyside Dam dropped to less than 100 cfs in 1986, 1987, 1988 and 1989 were, respectively, 6, 14, 9 and 2. The bulk of these episodes occurred during September and October, and so affected primarily migrating steelhead adults, but five occurred in May, affecting all outmigrating smolts and both adult steelhead and adult spring chinook: 76 cfs on 5/16/86, 95 cfs on 5/23/86, 18 cfs on 5/19/87, 90 cfs on 5/8/88 and 91 cfs on 5/27/88. Since 1995, flows below the dam from April 1 through October 31 are managed for a target flow based on TWSA. The target flow can range from 300 cfs to 600 cfs depending on the water supply for that year. Flows have dropped below 300 cfs on only three occasions since adoption of this policy.

Shorter-term fluctuations that do not approximate complete channel dewatering have also been and still are a problem. The Bureau of Reclamation has estimated these bi-hourly fluctuations can exceed 20 percent of the base flow (USBOR 2000). The YN used IFIM data collected by the USFWS for the reach below Sunnyside Dam to develop a regression between mean daily flow and wetted width, and then examined width fluctuations over a 24-hr period for the years 1982 – 1995. For the period April 30 through July 8, a time corresponding to fry emergence and early parr rearing for steelhead, they estimated that the mean absolute 24-hr width fluctuation was 7%, and that the mean annual maximum *decrease* in width over a 24 hr period was 20%. For the summer rearing period for steelhead yearlings (June 4 though November 11), the mean absolute width fluctuation was 6.6%, and the mean annual maximum width decrease was 26%. Data such as these persuaded the Bureau of Reclamation (2000) and Stanford (2001) that flow fluctuations are large enough to strand juvenile salmonids and their invertebrate prey in various shallow side channels and sloughs in the area, as well as to increase water temperatures in side channels and sloughs isolated by the fluctuations. A crude measure of the variability of a hydrograph is the coefficient of variation (CV) of mean daily flows over the period of record. By this measure, contemporary flows are slightly more variable than historical: the CV for regulated

1994-2000 flows below Sunnyside is 118%, whereas the CV for 1899-1907 flows is 95%. Inflows from Marion Drain, Toppenish Creek, Satus Creek and Sulphur Creek progressively dampen the fluctuations which become essentially undetectable by the Grandview gaging site at RM 55.4.

Figure 56 plots current (1994-2000) regulated hydrographs below Sunnyside Dam and at Kiona as well as the estimated historical mean monthly flows at Kiona. The same historical/current pattern seen below Sunnyside is seen at Kiona, the only significant difference being that the addition of discharges from Marion Drain and Satus and Toppenish Creeks cause Kiona discharges to be from 1,000 to 2,000 cfs greater than at Sunnyside.

The YN is in the process of exploring a number of flow-related parameters that influence the survival of smolts from the Chandler smolt trap to McNary Dam. The approach entails monitoring the detection rate of PIT-tagged smolts released at Chandler and detected at McNary and both McNary and John Day. Over a given time period, and assuming fish detected at McNary travel and survive at the same rates as fish that were not detected, the number of fish detected at both McNary and John Day divided by the number detected only at John Day represents an estimate of the "sampling rate" at McNary. The Yn developed time-stratified estimates of McNary sampling rates for tagged fish released in 1998 and 1999, and then used these rates to estimate Chandler-to-McNary survival for 122 individual releases of spring chinook, coho and fall chinook. Logistic regression was then used to determine the factors that were significantly correlated with the survival indices and a subsequent analysis of variance determined which factors remained significant even when paired with other significant independent variables. For yearling smolts (spring chinook and coho), survival from Chandler to McNary Dam correlated significantly with the following four factors:

Flow at McNary (MFLOW): $S = -1.37 + 9.53 \times 10^{-6}$ MFLOW[13]
$p = .004$
All smolts at Prosser (ALLSMLT): $S = 0.553 + 6.16 \times 10^{-5}$ (ALLSMLT)
$p = .008$
Hatchery smolts at Prosser (HATSMLT): $S = 0.753 + 8.00 \times 10^{-5}$ (HATSMLT)
$p = .011$
Flow below Prosser (PFLOW): $S = 0.532 + 1.54 \times 10^{-4}$ (PFLOW)
$p = .016$

The "all smolts" and "hatchery smolts" variables were the number of fish estimated to have passed Prosser Dam the day of the release. Mortalities between Prosser and McNary Dams are believed to be largely due to predation. The impact of varying numbers of commingled smolts on the survival probability of an individual outmigrant might be either positive or negative: positive if large numbers of commingled smolts confuse or satiate predators, negative if more smolts simply attract more predators or stimulate their feeding rates. These indirect effects mediated by predators have been termed "indirect predation", under the assumption that the impact of commingled smolts would be negative. Therefore nine factors (flow below Prosser and approaching McNary; water temperature at Prosser and McNary; turbidity at Prosser and McNary; mean smolt size and commingled smolts at Prosser and McNary) were investigated individually and together to determine which

[13] Measured in cfs. Because Columbia River flows at McNary are frequently over 100,000 cfs, the regression coefficient is rather small.

significantly correlated with survival individually and when paired with other significant variables.

The results shown above indicate that survival is positively correlated with flow below Prosser and approaching McNary, that the number of commingled smolts enhances survival, and that all of these factors explain a significant fraction of survival variability even after adjustment for the contributions of the other significant factors.

The survival of fall chinook smolts from Chandler to McNary correlated significantly with the following nine factors:

McNary spill (SPILL): $S = +10.14(SPILL) – 3.14$	$p = 5 \times 10^{-7}$
Prosser water temperature (PTEMP): $S = -.1413(PTEMP) + 8.61$	$p = 2 \times 10^{-5}$
Hatchery smolt density at McNary (FPIHAT): $S = -8.88 \times 10^{-6}(FPIHAT) + 1.46$	$p = 7.6 \times 10^{-4}$
McNary flow (MFLOW): $S = +1.2 \times 10^{-5}(MFLOW) – 3.47$	$p = 8.5 \times 10^{-4}$
McNary water temperature (MTEMP): $S = -.138(MTEMP) + 8.41$	p = .002
McNary turbidity (MTURB): $S = -.999(MTURB$[14]$) + 2.74$	p = .006
Hatchery smolt density at Prosser (HATSMLT): $S = +7.7 \times 10^{-5}(HATSMLT) – 2.45$	p = .01
Total smolt density at Prosser (ALLSMLT): $S = +5.8 \times 10^{-5}(ALLSMLT) - .437$	p = .01 and
Mean length of fish released (LENGTH): $S = -8.32(LENGTH) + 7.45$	p = .03

Hydrograph: impacts associated with diversion dams

Four major diversion dams are found in the lower Yakima, Wapato (RM), Sunnyside (RM), Prosser (RM 47.1) and Horn Rapids. Each of these dams affects juvenile and adult salmonids adversely, sometimes in association with the bypass system or fish ladder, and sometimes as a result of flow fluctuations or partial dewatering downstream.

Migrating juveniles incur losses as they pass through the bypass systems at all four dams. Northern pikeminnow congregate in the bypass outfall areas of Wapato, Sunnyside and Prosser Dams (Dunnigan 1999) and smallmouth bass congregate below Horn Rapids Dam (McMichaels 1999). Smallmouth bass (McMichaels, Battelle NW, personal communication, 2001) and Northern pikeminnow (Fast et al. 1991) also congregate inside Chandler Canal, between the headworks and the bypass drums, and possibly inside the pre-bypass sections of the canals at the other four dams as well. California gulls also congregate in the vicinity of Prosser Dam and Horn Rapids Dam (Phinney 1999). All of these piscivorous animals consume smolts and parr as they negotiate the pre-bypass canal and as they are discharged back into the river. The average loss of PIT-tagged smolts (spring chinook, fall chinook and coho) through the bypass system and outfall area at Prosser Dam/Chandler Canal was estimated at approximately 20% for yearling smolts and 40% for subyearlings[15] (YN unpublished data), although there was much variability in the data. Smolt loss in the pre-bypass section of Chandler Canal itself is usually much smaller – 2-5% for both yearling and subyearling smolts -- but usually increases significantly after mid-May to values in excess of 50%. These losses are primarily due to predators feeding in the canal or at the outfall.

At the Chandler bypass outfall, smolt losses to gull predation alone have been estimated at 1 – 2.5% over the years 1998-2000, but likely would have been considerably higher if flows had not been so high during the outmigration. Phinney (1999) observed that gulls cease feeding and begin leaving the Chandler outfall area when flows exceed ~4,000

[14] McNary turbidity is expressed as a Secchi disk reading. Therefore the higher the reading the lower the turbidity. A negative regression coefficient thus makes sense if one assumes most predators are visual and would find it more difficult to capture prey under turbid conditions.

[15] These estimates were made by simultaneously releasing groups of PIT-tagged smolts just inside the canal headworks and in the river below the bypass outfall area. The relative ratio of canal-released fish to below-outfall-released fish at McNary is an estimate of cumulative bypass/outfall losses (for well-mixed recovery data sets).

cfs, presumably because they cannot see prey in turbid, fast water. In the drought years of the late 1980', YN staff working at Chandler counted up to 200 gulls roosting on exposed waiting for smolts to exit the bypass pipe. Phinney estimated similar losses to gull predation at Horn Rapids Dam over the same time period, and observed a flow threshold of 13,000 cfs for feeding and congregation. Because gulls tend not to congregate in the vicinity of Wapato and Sunnyside Dams, it has been assumed that the mean cumulative bypass loss rates are lower there than at Chandler/Prosser.

Phinney (1999), McMichaels (1999) and others have speculated that most of the predation loss at canal bypasses is due to improperly designed outfalls. The outfall at Chandler/Prosser bends upward at a 90^{o} angle to prevent the orifice from being clogged with gravel by the river. Unfortunately this configuration, when combined with entrained air bubbles that "belch" explosively when suddenly released into river, causes smolts to be tossed to the surface in a disoriented state. The lower, slower and clearer the river when this happens, the easier it is for foraging predators. Accordingly, the YN and others have proposed that the outfall structures at all major dams on the Yakima be redesigned to "diffuse" smolts back into the river over as large an area as practicable. Phinney (1999) also recommended that the roosting rocks for gulls be removed at the Chandler outfall. The problem at Horn Rapids Dam, which diverts a comparatively small proportion of river flow, is not concentrated at the bypass outfalls but in the backroll just below the dam. Somewhat like smolts at the Chandler outfall, smolts passing over HornRapids Dam are tossed toward the surface in the backroll where they are easily taken by keen-eyed gulls and bass[16].

The final smolt impact associated with lower Yakima diversion dams is the effect of diversions at Prosser on smolts downstream. Prosser Dam diverts up to 1,500 cfs into Chandler canal, over half of which is routed through a powerplant 11 miles downstream and then returned to the river; the remainder continues down the KID canal to users in the Tri-Cities. During low-flow periods, flows in this "bypass reach" can become very low, delaying smolt outmigration and increasing the effectiveness of visual predators. Lower flows also expose boulders within the channel which increase heat transfer to the surrounding water. Since 1995 and passage of the YRBWEP legislation, flows in the bypass reach are kept between 300 and 900 cfs depending on TWSA. In addition, constraints have been put on the conditions under which flows can be diverted at Prosser for power generation. From April 1 through June 30, power production must cease (and diversions for power production be halted) whenever flows in the bypass reach fall below 1,000 cfs. From July 1 through October 15, power production must be subordinated whenever 450 cfs cannot be maintained in the bypass reach or the YRBWEP-mandated flows cannot be maintained, whichever is larger. From October 15 through March 31, power subordination is triggered by bypass flows of 450 cfs or less, or as negotiated.

Lower Yakima diversion dams have four impacts on adults: passage delay due to bedload clogging of ladders and/or large woody debris snagged against ladder exits; entrainment of fall chinook, coho and steelhead in Chandler Canal when it is dewatered for screen maintenance in the fall; and dewatering of fall chinook redds in the bypass reach when power generation resumes after the fall screen maintenance period.

Regarding adult entrainment in Chandler Canal, the left bank ladder at Prosser, which is the most heavily used by adult salmon, exits within a few feet of the entrance to Chandler Canal. Consequently, fall chinook, coho and the occasional steelhead are easily

[16] One of the reasons gulls leave Horn Rapids Dam at high flows is that the backroll is eliminated: flow over the dam smooths out.

entrained[17]. Many of these fish cannot or will not pass through the trash racks upstream of the screens and bypass and are consequently stranded when the canal is dewatered for fall screen maintenance. In 1998, about 200 adult fall chinook and 2 steelhead were salvaged during the dewatering process; no bull trout were found. The Yakama Nation coordinates with Reclamation on canal drawdown so they can use stranded fall chinook and coho as broodstock and release surplus fish back into the river.

Regarding the dewatering of fall chinook redds in the bypass reach, canal/screen maintenance has sometimes been scheduled in late October and early November – the peak of the fall chinook spawning season. Some fall chinook in the bypass reach are therefore likely to spawn at higher elevations in the streambed than would be possible if the full 1,500 cfs were being diverted at Prosser Dam. The redds these fish produce are therefore dewatered when maintenance is over and diversions resume.

Naches

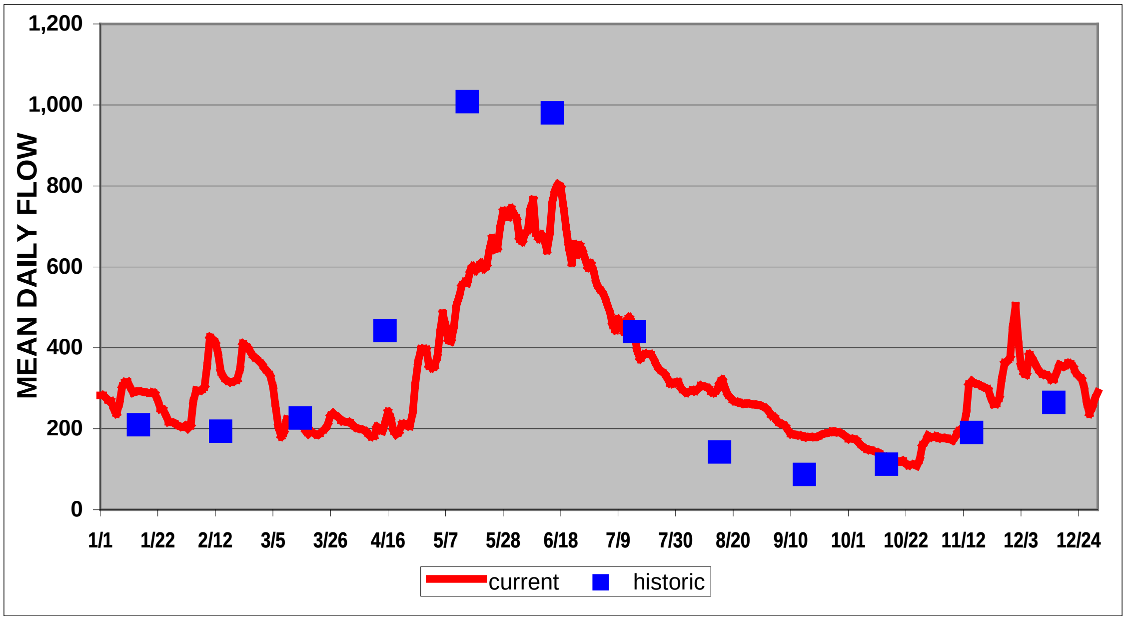
The Naches River is the largest tributary to the Yakima, extending 44.6 miles from its mouth at Yakima RM 116.3 to the point at which the Bumping River and the Little Naches River converge to form the Naches River. It has a moderate gradient averaging 0.58% (0.28-0.71% range) and contains a small, ~4-mile unconfined alluvial section centered on the Rattlesnake Creek confluence (Naches RM 27.8) and a large unconfined alluvial section extending from the Wapatox Dam (RM 17.1) to the Cowiche Creek confluence (RM 2.7). Outside of these alluvial areas the river is generally confined although not so tightly as to preclude a fair number of side channels and islands. Significant tributaries, from the mouth upstream, include Cowiche Creek, the Tieton River, Rattlesnake Creek, Nile Creek, the Bumping River and the Little Naches River.

The Naches River supports spring chinook, coho, steelhead, rainbow trout and bulltrout, as well as a number of other salmonid and non-salmonid species (WDFW 1998). Based on data from radiotagged adults (Hockersmith et al. 1995) steelhead spawn throughout the Naches and all of its tributaries except the Tieton and American River. Spring chinook spawn in the Naches largely above Rattlesnake Creek, in the Bumping, Little Naches, Rattlesnake Creek and the American River. Coho are in the process of being reintroduced to the basin and currently spawn primarily in the Naches below and just above the confluence with Cowiche Creek, with a handful spawning in the vicinity of the town of Naches. The spawning distribution of rainbow trout is unknown but is probably similar to that of steelhead – including the exclusion of the American River (spawning in the tributaries of the lower Tieton is probable given the presence of juvenile *O mykiss*). The reach from the mouth to Rattlesnake Creek confluence is the historical summer chinook spawning area.

Above the Tieton confluence, the historical "upper Naches" probably bore a fair resemblance to the river of today. Large woody debris and the scour pools and gravel bars they create would have been considerably more abundant, but confinement and high spring flows probably would have prevented the formation of massive log jams. Old growth timber (ponderosa pine below grading into Douglas fir) would have been found at the river's edge above Rattlesnake Creek, and small side channels and springbrooks in the wider portions of the valley would have been more common than they are today. Highway 410 parallels most of the left bank of the upper Naches now and virtually all of the embankment is riprapped. In many places summer homes and residences on the right bank are protected by riprapped

[17] Prosser hatchery, located less than a mile below Prosser Dam, uses primarily Chandler Canal water for rearing. Consequently, it is likely that many hatchery fall chinook, homing on the odor of their rearing water, voluntarily enter Chandler Canal.

revetments as well. Bedload movement is apparent in some of the more narrowly confined reaches today, and the right bank revetments have cut off historical side channels and springbrooks.



HKM Engineering 1990

Figure 57. Mean daily flow 1994-2000 (current) and estimated historical mean monthly flow, Bumping River above the American River confluence

Rattlesnake Creek was and is a very flashy, tightly confined creek. The alluvial fan at its mouth today would have been much larger historically, before the extensive channelization along its lower two miles, and trees transported from upstream would have lodged into jams at the mouth diverting flow into distributaries on either side as well as into the hyporheic zone to emerge as springbrooks downstream. This alluvial fan and its log jams have been cleared away to protect a bridge and homes in the area, drying up the springbrooks and whatever side channels have not been filled.

Perhaps the biggest difference would have been water temperature and substrate composition. Currently, summertime water temperatures all along the Naches can reach 72-73 ^{o}F (22.2 – 22.8^{o}C; Naches Ranger District, unpublished data). This increase is due to changes affecting the hydrology of the Bumping and Little Naches Rivers. Historically, summer flows out of the warm surface layers of Bumping Lake were considerably less than they are now under regulation (Figure 57). The Little Naches watershed had not been logged and therefore probably contributed cooler (if not necessarily more) water. It is in any case a fact that maximum water temperatures in the low 70s (Naches Ranger District, unpublished data) have been observed in both the Bumping and lower Little Naches Rivers near their mouths, where they merge to form the Naches. Despite the fact maximum temperatures, particularly in low flow years like 1992 and 1994, can be stressfully high, mean summer temperatures are higher than optimal but not critically high. Mean July and August temperatures at Clifdel (RM 38.8) over the years 1992 – 1999 were 60 and 63.4^{o}F (15.5 and 17.4^{o}C), respectively (USBOR Hydromet data).

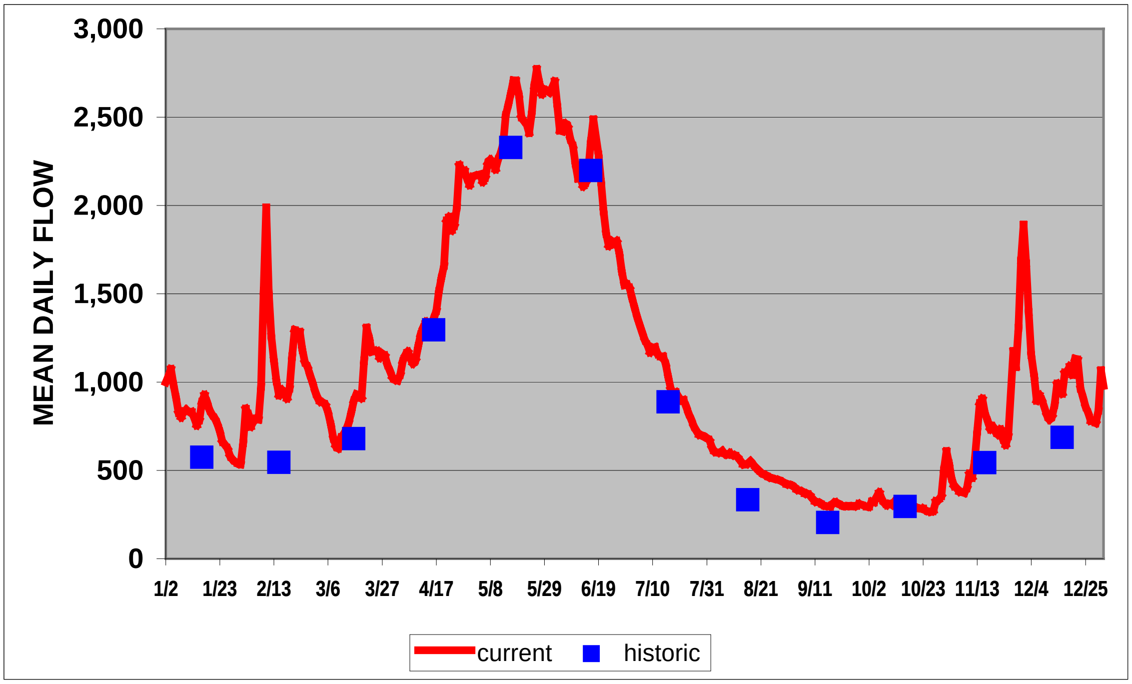


Figure 58. Mean daily flow 1994-2000 (USBOR Hydromet data) and estimated mean monthly flow (HKM Engineering 1990), Naches River at Clifdel (RM 33.8).

The substrate in historical times would have consisted of the same predominantly cobble/gravel mixture seen today although the percent fines would have been substantially lower. The watershed, particularly in the Little Naches subbasin, and riparian areas would have been intact, and there would have been no logging roads or skid trails. The percent fines (<0.85mm) in the Naches River has never, to the authors knowledge, been determined, but the percent fines in the Little Naches over the period 1991-1996 have ranged from 11 to 24%. By contrast, percent fines over the same period in the American River have consistently been about 10% (J. Matthews, YN, personal communication, 2000).

As is evident if Figure 58, the hydrograph in the upper Naches (Clifdel gage, RM 38.8) over the past seven years is virtually indistinguishable from the mean historical hydrograph. This is to be expected in a river reach subject only to the regulatory capacity of 33,000 AF Bumping Reservoir

Historically, the 14.8 miles of river between the Tieton confluence and Cowiche Creek spread over a mile-wide valley in multiple channels and springbrooks. As would be expected in a complex channel below a transport reach, large woody debris was abundant and retained gravels transported from upstream, eventually forming some of the islands that still exist. As usual in unconfined reaches, flooding during the peak of spring runoff was an annual event. The dominant riparian tree was and is the cottonwood, patches of which at various stages of maturity were found interspersed with willow and dogwood on more recently disturbed areas. The valley reached its maximum width in the lower two to three miles of the reach, before being abruptly pinched off by pincers of basalt just above Cowiche Creek. This was a zone of strong upwelling, and springbrooks and wall-based channels erupted at numerous points on the left bank, ultimately coalescing into a substantial return channel that came to be known as Buckskin Slough. A large side channel now called the South Naches Channel diverged from the right bank at the city of Naches (RM 14.0) and flowed over a low terrace for about four miles, collecting springbrooks and wall-based channels erupting at the foot of the steep valley wall to the southeast before reentering the Naches. Below the nick point at the Cowiche confluence, the river was once again unconfined. Likely this was historically an alluvial fan, as bedload washed at high velocity settled out in the slower waters below, creating side channels and springbrooks downstream and entering the Yakima in multiple channels.

Development has radically changed the structure and hydrograph of the lower Naches. The downstream end of the valley has been converted to orchards, residences a golf course/trailer park/RV Park and, below the Cowiche confluence, a freeway and shopping mall. Most of the springbrooks and side channels that funneled into Buckskin Slough have been filled, but a number still emerge from the ground for short distances and the lower 2 miles of Buckskin Slough itself still exists and is heavily used for spawning by coho and occasionally by steelhead. Highway 12 bisected the floodplain and restricted the river to half or less of its historical width. Perhaps half of the original cottonwood stands remain, the rest having been cleared for various kinds of development. Large woody debris is scarce, probably because of accelerated velocities and removal by private citizens, although some was recruited from upstream during the flood of 1996. South Naches channel as well as a number of smaller springbrooks and side channels on the left bank, have been channelized and converted into irrigation canals. The diversity of channel types has been greatly reduced, and what was formerly a valley-wide complex of main channels, side channels, wall-base channels, sloughs and wetlands is now generally two or three larger channels connected by braids, with a fair number of narrow, brushy side channels between a quarter mile and four miles. The river is usually confined on both sides either by basalt canyon walls or by riprapped dikes or road embankments. The lowermost 2.7 miles below Cowiche Creek has been tightly confined against basalt walls by the embankment of Highway 12 and effectively converted into a fast run. The river did, however, change course after the flood of 1996 and now runs through the middle of a stand of cottonwood for about a mile.

As important as any of the geomorphological changes is the change in substrate character and its implications for steelhead spawning. The proportion of fines in the lower Naches appears to be quite high. No McNaeil samples have been analyzed from the lower Naches, but it is apparent to the casual observer than the dominant substrate particles are from one half to three quarters embedded. The dominant substrate type as well has changed. Whereas gravel bars formed behind log jams and debris piles historically, the narrower, faster flows of the Naches now apparently transports most smaller particles into the middle Yakima. The substrate of the lower Naches is now a curious mix of large (5 – 7 in) cobble and sand except in some floodways and side channels where smaller gravels heavily embedded in sand are found. It is very unlikely that steelhead or even spring chinook would be able to spawn in the large rubble in the main channel now, but steelhead can and do spawn in the lower Naches. Indeed, over 40% of all the Naches radiotagged steelhead that spawned in the Naches in the Hockersmith et al. (1995) study spawned in the lower Naches. Apparently, steelhead are spawning in higher elevation side channels and floodways that are inundated during April and May. The viability of many of these redds is, however questionable, given the rapid drop of flows during the late spring. It is very likely that many are dried up before emergence is complete in June and July.

The hydrograph has been changed by factors acting both within and outside of the lower Naches. The major impact is from the "flip-flop" river operation scheme. As previously mentioned, this pattern of water retention and release for upper Yakima and Naches storage reservoirs spares upper Yakima spring chinook redds by forcing spawners to construct redds lower in the deeper part of the channel where dewatering is much less likely when releases are cut back in the winter to fill the reservoirs. In practice flip-flop consists of releasing virtually all of the water needed by WIP and SVID from the upper Yakima reservoirs until early September. During this time, releases from Rimrick (and to a much lesser degree Bumping) are reduced. Then in early September, the pattern of releases is reversed ("flip-flopped"), and releases from Rimrock and Bumping provide all the water needed for the diversions at Wapato and Sunnyside Dam, and the upper Yakima releases are curtailed. September is the beginning of the spawning period in the upper Yakima, and is late enough in the season that spring chinook spawners in the Naches drainage have all passed above the Tieton confluence in the Naches. Thus, upper Yakima spawners are forced to spawn low in the channel and Naches and American River pre-spawners are not affected by the dramatically increased flows in the lower Naches. Within the lower Naches, up to 450 cfs is diverted at Wapatox Dam (RM 17.1) year round. Most of this water is used for hydroelectric generation and all but 50 cfs (which is used for irrigation April 1 – October 14) is returned to the river at a powerplant located at RM 9.7. There are in addition several clusters of smaller diversions on the lower Naches below Wapatox. The South Naches Channel (RM 14.0) diverts up to 141 cfs (USBOR Hydromet data) for seven small irrigation canals serving orchards on the right bank of the lower Naches, and discharges some of its diverted flow back to the river at about RM 10. Below the South Naches Channel diversion, the Kelley-Lowerey (RM 13.7) diverts up to 30 cfs, the Gleed (RM 9.4) up to 40 cfs, the Congdon (RM 8.8) up to 55 cfs, the Chapman-Nelson (RM 6.0) up to 40 cfs, the City of Yakima (RM 3.6) up to 15 cfs and the Naches-Cowiche (RM 3.6) up to 40 cfs. The portion of the lower Naches most severely impacted by all of these diversions is the so-called "bypass reach", which extends 7.4 miles from the Wapatox diversion to the powerplant outfall. Within the bypass reach, the Naches River must supply the needs of the South Naches Channel and the Kelly-Lowerey Ditch before being recharged with ~400 cfs of Wapatox water at the powerplant. During drought years, flows can become exceedingly low in the bypass reach, and stranding in the many side channels and braids becomes a distinct hazard for juvenile salmonids.

Figure 59 depicts the regulated 1994-2000 mean daily flow below the Wapatox diversion, the regulated flow at the same site for the period 1982-1993 (a relatively low-flow period), and the estimated mean monthly historical flows for the Naches below the Tieton confluence (HKM 1990). Since 1994, the regulated and historical flows match up pretty well, with moderately lower spring flows as runoff is retained in Rimrock for flip-flop, a somewhat lower seasonal low flow and a distinctly non-normative spike in September and October representing flip-flop releases. In low-flow years, however, such as the period 1982 – 1993, the diminution of the spring peak is much more pronounced as is the intensification of the seasonal low flow period.

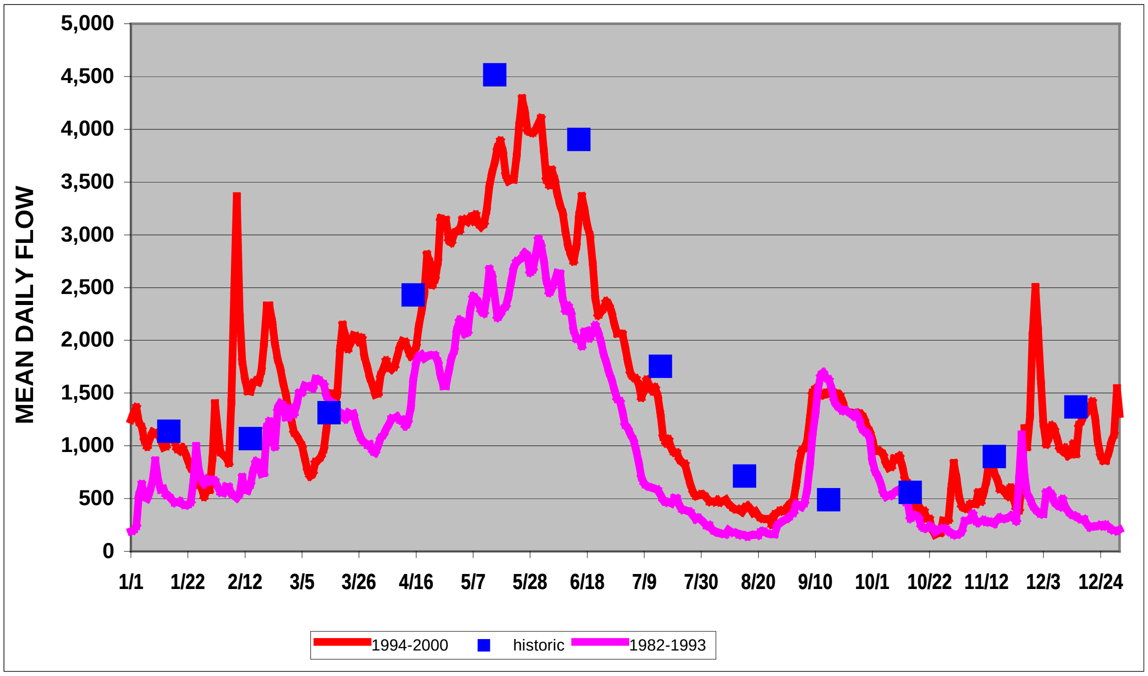


Figure 59. Mean daily regulated flow for the period 1994-2000, 1982-2000 (USBOR Hydromet data) and estimated mean monthly historical flows in the Naches River below Wapatox Dam

Although not examined quantitatively, flip-flop flows appear to be sediment competent (Mark Lorang and Bruce Watson, personal observation) and are maintained for at least three weeks—much longer than a "natural" flood event. Although spring chinook redds are saved in the upper Yakima as a result of the flip-flop management, there has been little or no effort to understand or monitor the effects of this flow regime either on the upper Yakima or on the lower Naches River. In the upper Yakima, significant stranding of benthic invertebrates may occur and numerous side channel habitats critical to the completion of many different species life histories, including juvenile salmon, are disconnected. In the Naches River, sediment competent flows likely result in rapid rates of cut and fill avulsion, as well as generating a spectacular annual disturbance event, the magnitude and duration of which is well beyond that occurring historically. In both the upper Yakima and the lower Naches, organisms specifically adapted to the natural and predictable disturbance regime would likely be unable to adapt to the anthropogenic regime and would suffer declines in density and productivity (Resh et al. 1988). This applies both to the post-reservoir flow regime and particularly to the alteration of that regime via flip-flop. The flip-flop regime be examined carefully, a process made difficult by the lack of quantitative data (Stanford and Snyder 2000).

A particular concern affecting juvenile salmonids is that the relatively sudden and dramatic increase in flow during flip-flop might displace juveniles downstream, perhaps all the way into the much less hospitable lower Yakima. At a minimum, the increases in flow associated with flip-flop can cause fish to vacate feeding territories and migrate to new areas, increasing competition and stress, reducing growth, and increasing the likelihood of mortality (CSRP 1990). An impact of this sort would seem inevitable unless fish, necessarily concentrated in the center of the main channels by late August, are able to find and make use of protected side channels before becoming exhausted and moving downstream to find better habitat. If this occurs for subyearling steelhead, the probable outcome is death, as it is unlikely that they could survive another entire year in the lower

Yakima. It should be noted that the Bureau of Reclamation is aware of this particular issue, and since 1994 has imposed the flip-flop operation much less rapidly than before. Previously, flows in the Naches were increased and flows in the upper Yakima decreased over about a 3-day period. Since 1994, the change has occurred over a week to 10-day period, in an effort to allow lower Naches salmonids time to find and make use of protected side channels and braids.

A final flow-related problem concerns stranding in or exclusion from the side channels in the bypass reach. The Yakama Nation, the USFWS and the USBR floated and walked the lower Naches the summer of 2000 with the intention of determining the flows which inundated most side channels as well as those that dewatered all of them. To expedite their study, the USBR provided a number of comparison flows. It was determined that all side channels would be dewatered when flows were less than approximately 130 cfs, and that most would contain some water when flows were 630 cfs or greater. Figure 60 depicts mean daily flows in the bypass reach (flows below the South Naches Channel) for July and August for the years 1981 – 2000. Also indicated on Figure 60 are heavy lines indicating flows for adequate side channel inundation and flows for total side channel dewatering. It is quite evident that there is at least a short period during most years when the side channels are nearly or totally dewatered. Perhaps more troublesome are the number of years for which flows are competent through early July of at least filling some of the side channels, but then fall below the total dewatering level. When flows are "side channel competent", it is likely that fry and parr are recruiting to them. The impacts attributable to stranding are most likely directly related to the number of recruitment/stranding episodes per year, as well as the suddenness with which side channel competent flows

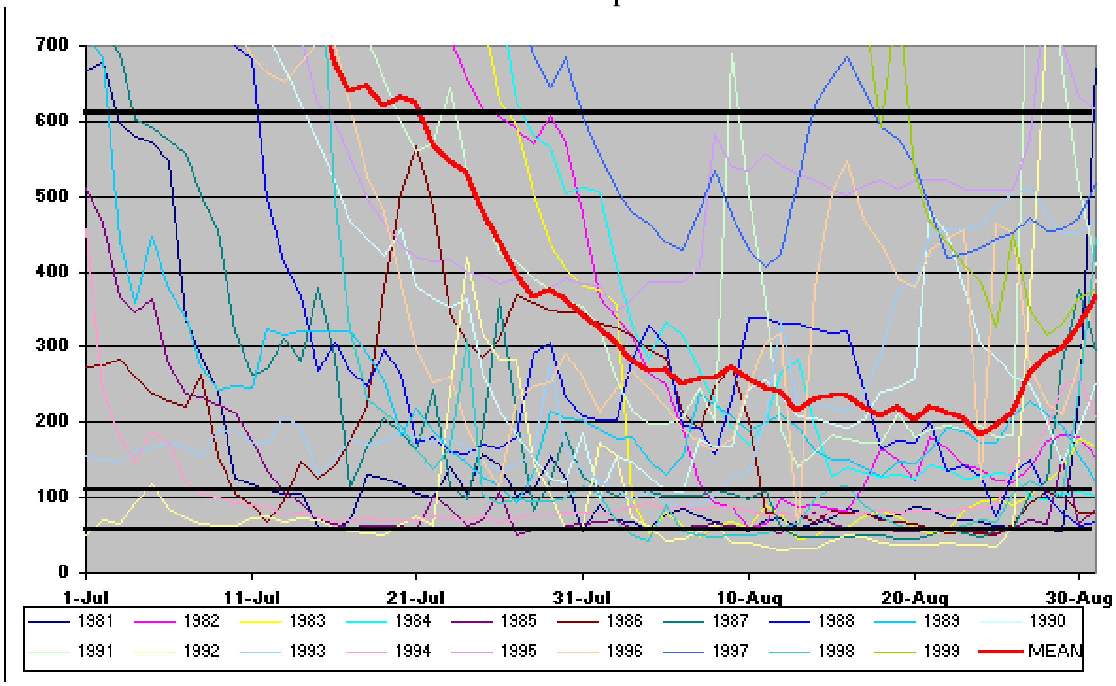


Figure 60. Mean daily flows in the bypass reach (flows below the South Naches Channel) for July and August for the years 1981-2000

Excursions from state water quality standards for water temperature have been documented on the Naches River, which is listed on the CWA Section 303(d) impaired water quality list for pH, Silver (further sampling recommended as not consistent with other water quality samples), and temperature. In addition, water temperature excursions are documented for Gold Creek (tributary to upper Naches River, which is also on the 303(d) list. Of the these water quality problems, the most significant is temperature. Although the mean July and August water temperatures in the lower Naches over the years 1988-2000 are only 62.2°F and 64.1°F (USBR Hydromet data), maximum single day mean temperatures over this period have reached the mid 70s. Elevated temperatures can be expected to constitute a significant problem during very low flow years such as 1992 or 1994, when the entire flow of the stream is concentrated in a trickle in the center of the steambed, especially in the bypass reach.

Naches Tributaries (exclusive of the American)

Although a great many tributaries flow into the Naches River, the most important streams from the standpoint of fish production are: Cowiche Creek (right bank RM 2.7), the Tieton River (right bank RM 17.5), Rattlesnake Creek (right bank RM 27.8), the Little Naches River (left bank RM 44.6) and the Bumping River (right bank RM 44.6). The American River is a tributary of the Bumping, and therefore also of the Naches, but is discussed separately because of its uniquely pristine status and the unique run of spring chinook it supports. The Tieton and Bumping Rivers are blocked by Rimcock and Bumping Dams, respectively. Only the "lower" Tieton and Bumping -- the portion below the dams – will be discussed here as the portion above the dams have already been discussed in the Headwaters section.

Although of different size in terms of mean annual flow, all Naches tributaries have a similar, moderate gradient of from slightly less than 1.0 (Bumping River below American confluence) to slightly more than 2.0% (Rattlesnake Creek). The Little Naches River, Rattlesnake Creek and Cowiche Creek are unregulated (although all save the Little Naches are diverted); the Tieton and Bumping Rivers are regulated. Estimated maximum and minimum mean monthly unregulated flows (HKM 1990) for these Naches tributaries are listed in Table 28.

Table 28. Estimated unregulated maximum and minimum mean monthly flow, major Naches tributaries

Stream	Maximum Flow	Month of Maximum Flow	Minimum Flow	Month of Minimum Flow
Bumping (at mouth)	1,668	May	145	September
Little Naches (at mouth)	765	May	48	September
Rattlesnake Creek (at mouth)	441	May	48	September
Tieton (at mouth)	1,199	May	254	October
Cowiche (at mouth)	141	May	30	October

HKM 1990

General Character and Utilization

The description Bryant and Parkhurst provided in 1935 for the lower Bumping is probably a good likeness of the historical lower Bumping as very little development, other than the construction of Numping Dam, has occurred in the watershed. The same can be said for the Little Naches (save for recent logging), Rattlesnake Creek (save for the channelized lower mile). The riparian community of the lower 3-4 miles of Cowiche Creek has been altered but not severely degraded by residential development; the same is true of the middle portion of the creek in regard to agricultural development. The riparian community of the lower Tieton has been significantly altered by the construction of Highway 12 immediately adjacent to the stream and the condition of the channel has been radically altered by the regulated hydrograph.

In 1935, Bryant and Parkhurst wrote the following description of the lower Bumping River: “The Bumping River flows through a mountain valley with steeply sloping sides. In some areas the cliffs rise sheer from the river’s edge; in others the valley widens and the stream flows through grassy meadows and relatively open forests. The entire valley is heavily forested with conifers – principally pine but with fir, larch and cedar also present. Alder, cottonwood and willow border the streambanks and in some areas form dense thickets. There is no cultivation of the land carried on in this valley, the whole of it lying in the Rainier National Forest. Excellent spawning beds and good riffles are present throughout the entire area surveyed although large rubble [boulders] is plentiful in the stream throughout its length. Pools are not numerous but those present are large and well-protected. These, and the presence of large boulders in the stream, provide adequate resting places and excellent cover for migrating salmonids.” The only change to this description, which is appropriate both to the historical and contemporary Bumping River, is that large woody debris is relatively abundant and that small side channels are usually present in the “grassy meadows” referred to.

As to fish species present, Bryant and Parkhurst stated that “In former years, large numbers of chinook salmon were said to enter this stream...[but] no other species of salmon was reported in the river and no report of the steelhead run could be ascertained...Rainbow, dolly varden and cutthroat trout and whitefish are present in the stream.” Except for the fact that steelhead are now definitely known to spawn and rear in the stream, the same species are present in the Bumping now and were present historically.

The Little Naches River watershed is moderately large (102 mi^2) and heavily timbered, although extensive clear-cutting has occurred over the last decade. Significant tributaries accessible to upstream migrants include Crow Creek, Quartz Creek, the North, Middle and South Fork and Pyramid Creek. Spring chinook, steelhead and bulltrout, as well as other salmonid and non-salmonid species, spawn and rear in the Little Naches and/or its tributaries (WDFW 1998). Until the fishway at Salmon Falls (RM 4.4) was installed in 1987, spring chinook spawning occurred only in the lower 4.4 miles (CBSP 1990).

The description Bryant and Parkhurst provide of the Little Naches in 1935 is likely a good match for the historical stream. “The Little Naches River flows through a narrow, heavily wooded mountain valley. In many places the side walls are canyon like, rising sheer from the river on one side or the other. The forests on the side slopes and river bottoms are composed principally of pine with fir, larch, hemlock and cedar also present. A few scattered cottonwood and alder are found along the streambanks. none of the valley is under cultivation...This is a fast moving stream with excellent riffles and fine spawning gravels...Deep holes are scattered throughout its course providing excellent cover and resting pools for migrating salmonids. Numerous windfalls and small log jams also provide cover...there is a small cascade [Salmon Falls] with a total drop of about eight feet [at RM 4.4]. This falls is no obstacle to upstream migrants, except in extremely low water, as it is not a direct drop, but tends to form about a 70^{o} down stream apron.” Their description of fish species present probably also matches the historical condition:” Chinooks were reported. last year, to be present in considerable numbers in the Little Naches...No other species of salmon is reported to use this stream...Steelheads probably spawn in this area...The trout found in this stream are predominantly cutthroats with a few...rainbow also present." The only changes that would be proposed for the historical salmonid community are that coho were probably present, given the frequency and quality of pools, and bulltrout were almost certainly present at least in some of the tributaries.

The Rattlesnake Creek watershed penetrates a very mountainous area, is slightly larger than other Naches tributaries (134 mi^2) and is tightly confined in a very deep and steep-walled canyon above the Little Rattlesnake confluence (RM 1.1). Major tributaries accessible to upstream migrants include Little Rattlesnake Cr. (RM 1.1), the North Fork (RM 7.7) and Hindoo Creek (RM 13.2). Now and historically, runoff is flashy and base flows can quite low. Where side slopes of the canyon are not so steep as to preclude them, conifers are abundant. Before development and channelization, the lower several miles of the stream were fringed with dense growth of alders, willows and cottonwoods; the same was and is still true of the headwaters of the drainage. The middle canyon reaches were and still are virtually devoid of woody vegetation because the spring freshet is large enough to strip the banks and scour the stream bottom, in some places to bedrock. Pools are relatively numerous throughout, but usually lack cover, and the entire stream save the depositional area near the mouth is lacking in large woody debris. Both historically and at the present time, Rattlesnake Creek supports spring chinook, steelhead, cutthroat trout and bulltrout, as well as non-salmonids (WDFW 1998). Chinook redds are usually found from the mouth of Rattlesnake Creek to the Little Rattlesnake, although Naches Ranger District biologists discovered several spring chinook redds in Rattlesnake Creek above the North Fork in 1998 (K. Lindhoerst, USFS, personal communication, 1998). Bulltrout redds are usually found above North Fork confluence (WDFW 1998), and rearing occurs in the mainstem as well as Hindoo Creek.

The lower Tieton flows through a narrow, heavily forested canyon with steep side walls. The floodplain is minimal and the stream rarely flows through more than a single channel. Before development, the lower portion of the stream was bordered by relatively open stands of Ponderosa pine and willow, alder and scrub oak, and the upper portion by pine and fir. The river now is confined by the canyon walls on one side and the embankment of Highway 12 on the other for almost its entire length. Because of the natural confinement, large woody debris was probably was never abundant, and the few pools present were generally associated with large boulders. The lower half of the reach has a slightly lower gradient and probably contained point bars of spawning gravel historically, but the substrate of the steeper upper section probably always consisted primarily of large rubble. Although spring chinook, steelhead, rainbow trout, cutthroat trout and bulltrout historically spawned and reared in the lower Tieton, these species have probably been extirpated by high and variable flows associated with the delivery of irrigation water (WDFW 1998). Tributaries to the lower Tieton are small, flow through shrub-steppe, and sometimes go dry in the summer.

Cowiche Creek drains another moderately large watershed (120 mi^2) and flows 7.5 miles through a very narrow canyon before splitting into South and North Forks. The forks flow through about nine miles of dry open grasslands before entering a forest that gradually changes from pine/scrub oak/willow to Douglas fir. Cowiche Creek and its forks is confined throughout its length – tightly so in the canyon – and never contained extensive anastomosing reaches, although beaver dams and ponds were and still are common below the forested area. Historically, Cowiche Creek supported steelhead, rainbow and cutthroat trout, coho and probably a small number of spring chinook in its lower most reaches. These species are still present in the accessible portions of the creek, although spring chinook apparently only use the creek for juvenile rearing now (WDFW 1998). There have been recent, unconfirmed reports of steelhead spawning in the South Fork and Reynolds Creek, a South Fork tributary (WDFW 1998), although this seems unlikely as a number of irrigation dams on the South Fork are thought to be impassible.

The following section describes the changes that have occurred since historical times in each of these tributaries. Changes will be described in terms of access, channel conditions, substrate, riparian conditions, water quality, and water quantity.

Fish Access

Installation of fish passage facilities at Salmon Falls (RM 4.4) in 1988 allowed anadromous access to approximately 18 miles (252,853 yd^2) of habitat (WDFW 1998, CBSP 1990). The Yakima-Tieton diversion dam at RM 14.5 of the lower Tieton is a barrier to upstream migration at low flows (WDFW 998)

Adult access and juvenile passage is the primary limiting factor in Cowiche Creek. An Alaska steep pass fishway was installed at the Yakima City Canal at the mouth of Cowiche Creek and probably provides adequate passage for adults. A wooden plank diversion dam just below the confluence of the NF and SF (RM 7.5) may be passable at high flows, but three other concrete dams on the South Fork at RM 1.3, 3.9, and 4.4 are thought to be impassible at all flows. The Yakima City Canal is screened, but the other four diversions are not (WFDW 1998). A debris jams at the trestles of an abandoned railroad spur along lower Cowiche Creek have formed in the past and have possibly impaired access. Beaver dams are common on both Cowiche Creek and the South Fork, and might restrict access to coho once passage problems at the four diversion dams were eliminated (CBSP 1990). An 8-ft cascade at RM 14.2 of Rattlesnake Creek may represent a passage barrier at low flows (Bryant and Parkhurst 1950).

Channel Conditions

The lower Bumping is a stable, pocketwater type stream, with a few short side channels in lower gradient flats. Upstream of Salmon Falls, habitat in the Little Naches nearly pristine, with abundant spawning gravel, excellent riparian condition, adequate summer flows, and plentiful large woody debris and instream cover (CBSP 1990). However, the 4.4 miles of the Little Naches below Salmon Falls was severely degraded by a series of floods in the late-1970s, and by an emergency campground restoration and protection project that removed deposited bedload material, widened and channelized the riverbed, and eliminated riparian vegetation (CBSP 1990). An instream restoration project completed in 1988 included the installation of large boulders intended to scour holes for holding and rearing habitat and the planting of riparian vegetation. This project was not successful and the lower 4.4 miles of the Little Naches now affords the poorest spawning and rearing habitat in the drainage. High flows associated with summertime releases of water from Rimrock Reservoir have swept the lower Tieton clean of gravel, in many places down to bedrock. The moderate gradient of Cowiche Creek and its forks is associated with many pools, riffles, and glides. large woody debris and overhanging/submerged vegetation is abundant in the mainstem and South Fork. Banks are stable except where grazing-induced sloughing has occurred from RM 10 to 12 on the South Fork and on the lower three miles of the North Fork (WDFW 1998). From the mouth to the confluence of Little Rattlesnake, the creek is channelized (CBSP 1990)

Substrate Condition

Although extensive gravel bars are not often found in the lower Bumping, patch gravel of high quality associated with large woody debris and large boulders is well distributed. Spawning gravel is abundant in the Little Naches River and tributaries, although fine sediments levels range from 12 to 24 percent (CBSP 1990; J. Matthews, YN, personal communication, 2000). Deposition of fine sediments has increased since the initiation of large-scale clearcutting in the upper watershed (CBSP 1990, WDFW 1998). In the lower Tieton, the quality of the small pockets of gravel that still exist is good, although heavy rains increase turbidity due to large natural slide areas (WDFW 1998). There are enough gravel bars in Cowiche Creek and the South Fork for spawners to fully seed the available rearing habitat (CBSP 1990, WDFW 1998). Siltation due to riparian overgrazing is moderate, except for the North Fork, where low flows allow fine sediment to settle (CBSP 1990). Spawning habitat in Rattlesnake Creek and its tributaries is generally limited to patches except in the lower mile. Substrate consists primarily of large cobble and gravel, and generally contains a low percentage of fines. Bedload movement is frequent and areas scoured to bedrock are common in the canyon. Substrate condition in the lower Bumping River downstream is fair to good, with very little sedimentation of gravels (CBSP 1990, WDFW 1998). The Bumping does, however, has many bouldery reaches unsuitable for spring chinook spawning, but which are probably adequate for steelhead (CBSP 1990).

Riparian Condition

The riparian corridor on the Bumping River is generally excellent, except in increasing numbers of areas where there are clusters of summer homes, with associated removal of riparian vegetation and riprap armoring of the streambanks (WDFW 1998). In the Little Naches, riparian condition is excellent upstream of Salmon Falls (CBSP 1990, WDFW 1998), but poor below (floods and channelization described previously). The condition of the upper watershed in upland area has, however, been damaged by extensive clear-cutting. Riparian condition in the lower Tieton is reasonably intact except where eliminated by the embankment of Highway 12 (WDFW 1998). Riparian vegetation in Cowiche Creek consists of willows, alder and aspen, and is dense along most reaches, even in areas of residential development or cropland (CBSP 1990, WDFW 1998). Upstream of the Little Rattlesnake confluence, riparian conditions along Rattlesnake Creek are good where the canyon walls are not too steep to support trees (Bryant and Parkhurst 1950).

Water Quality

The Bumping River is listed on the CWA 303(d) impaired water quality list for water temperature. There were numerous excursions from the temperature standards documented on the Bumping River at the American Forks campground from 1991-1994, and the USFS has documented instances in which the maximum temperature exceeded 70^{o}F (21.1^{o}C). Water quality in the Little Naches is quite good except occasionally for temperature (WDFW 1998). The following Little Naches tributaries have been placed on the CWA Section 303(d) impaired water quality list for temperature: Bear, Blowout, Mathew, and Crow Creeks. Water temperatures in excess of 70^{o}F (21.1^{o}C) have been observed in the lower Little Naches itself (Naches Ranger District, unpublished data). Water quality is not an issue in the lower Tieton (CBSP 1990, WDFW 1998). Cowiche Creek is on the CWA Section 303(d) impaired water quality list for fecal coliform, instream flow, and temperature; the North Fork is listed for fecal coliform and temperature; the South Fork is listed for fecal coliform and temperature; and the South Fork tributary of Reynolds Creek is also on the 303(d) list for water temperature. Excursions from state water quality standards for water temperature have been documented on both Rattlesnake and Little Rattlesnake creeks, which are listed on the CWA Section 303(d) impaired water quality list for temperature. Other than temperature water quality in Rattlesnake Creek generally good.

Water Quantity

Water quantity is not a substantial issue in the lower Bumping except for rare periods of low flow associated with the malfunction or repair of the outlet structure at Bumping Dam. In the Little Naches, there has been some concern that clearcutting and fires in the upper watershed of the would increase peak flows, possibly to damaging levels, as well as decreasing already marginal summer low flows. There is, however, no conclusive evidence of a change in the hydrograph (CBSP 1990; Figure 62). Low fall flows probably limit production of spring chinook in the Little Naches by reducing the quantity of suitable spawning habitat (CBSP 1990, WDFW 1998).

The hydrograph of the lower Tieton River has been reversed as a result of impoundment above Rimrock Dam and water releases for irrigation needs. The natural period of peak flows has been shifted from April-June to August through mid-October and increased in magnitude by about a third (Figure 61), from values on the order of 1,200 cfs to 1,800 cfs. Low flows during winter have been decreased radically, from historical values in the neighborhood of 200 cfs to values as low as 8-10 cfs in the past seven years, and to zero in the past[18]. Any salmon redds that may be constructed in the fall are probably dewatered in the winter (CBSP 1990). Flows for steelhead, which spawn in April and May, are quite variable, averaging 620 cfs since 1994, but with a range of 14 to 2,230 cfs. Flows during the subyearling rearing period of August through October are also quite variable, but generally higher, with a mean since 1994 of 795 cfs and a range of 15 to 2,458 cfs. It therefore is likely that any steelhead redd deposited in the lower Tieton would have equal chances of being dewatered or scoured, and that subyearling parr would have roughly equal chances of being stranded or flushed from the system. (USBR Hydromet data).

Instream flows in the mainstem and South Fork Cowiche are perennial although irrigation withdrawals can reduce flows to less than 1 cfs during July, August and early September (USBR Hydromet data). Spring-fed flows in the North Fork Cowiche are perennial except from the mouth to just above the town of Cowiche, where diversions dry the streambed except during spring runoff (WDFW 1998). Chinook spawning in Rattlesnake Creek in September is probably limited by low flows; higher flows in April and May favor steelhead spawning.

[18]In the drought year of 1977, flows below the Tieton Diversion Dam at RM 14.2 were zero from October 12 through October 31.

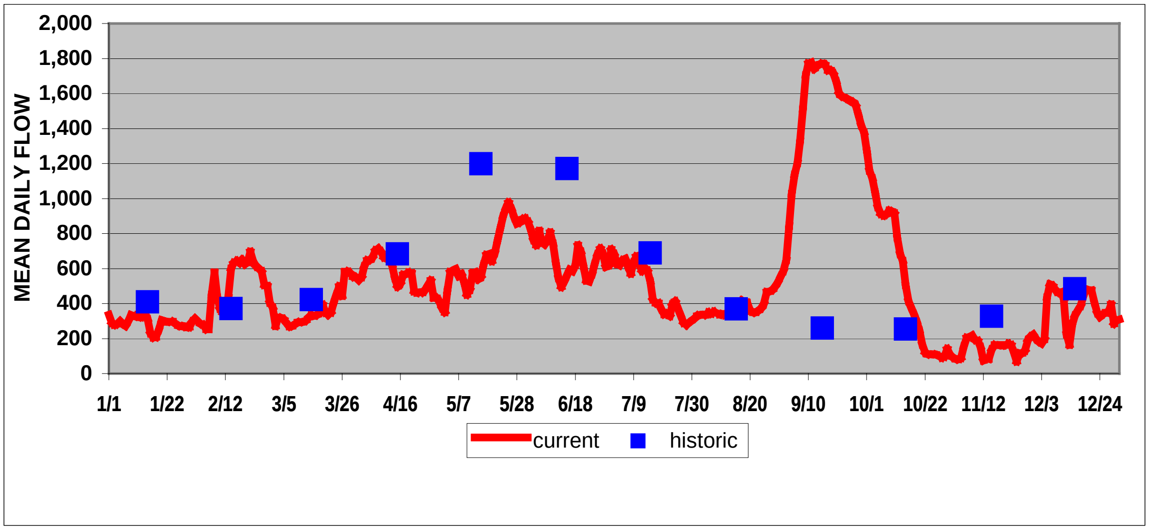


Figure 61. Mean daily regulated ("current") flows, 1994-2000, below the Tieton Diversion Dam (USBR Hydromet data) on the lower Tieton River, and estimated unregulated ("historic") mean monthly flows at the same site

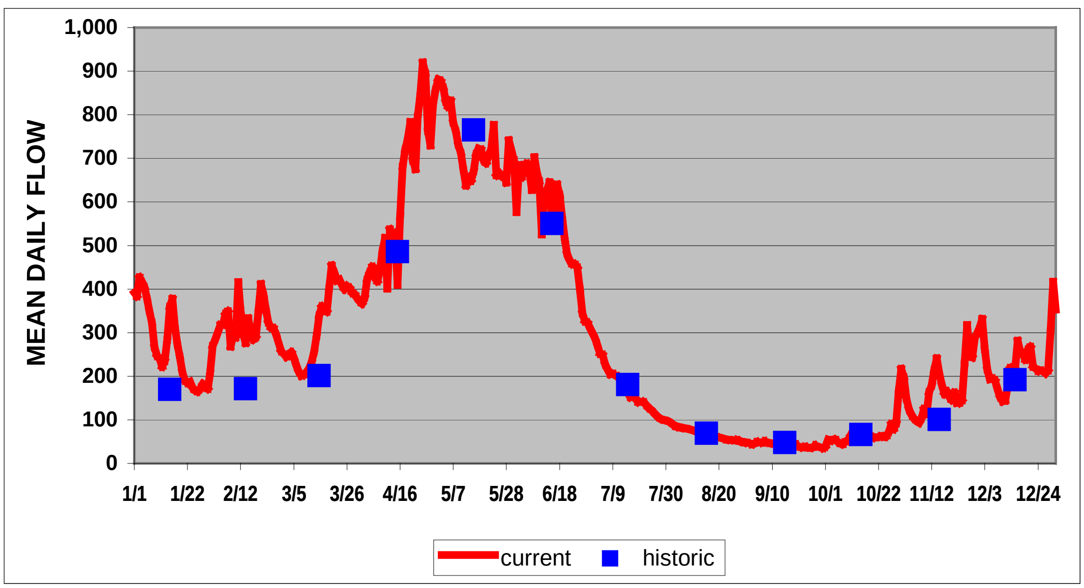


Figure 62. Mean daily regulated ("current") flows, 1994-2000, at the mouth of the Little Naches River (USBR Hydromet data), and estimated unregulated ("historic") mean monthly flows at the same site

American River

The American River supports spring chinook, brook trout and bulltrout, as well as other salmonid and non-salmonid species (WDFW 1998). American River spring chinook area genetically distinct stock consisting primarily of 5-year-old fish. Fluvial bulltrout redd index areas are located in the American River watershed in and around Union Creek (RM 11.5) and upstream of Lodgepole Campground RM 15.5)(WDFW 1998). The American River is the most productive spring chinook reach in the Yakima Subbasin, and also has the highest density of fluvial bulltrout redds in all of the Yakima watershed, particularly around and upstream of Union Creek (WDFW 1998). In their survey of the American River in 1935, Bryant and Parkhurst (1950) reported that " rainbow, cutthroat and Dolly Varden trout are plentiful in this stream in abundance in the order named", and that "no steelheads or species of salmon other than chinooks are reported to be present in this stream although it is probable that steelhead do make a spawning migration into the area". These reports are at variance with the observations of Yakama Nation biologists, who have rarely if ever observed adult or juvenile *O. mykiss* in the American River, as well as with the steelhead radiotagging study of Hockersmith et al. in which no tagged fish was observed entering the American River. The current scarcity of rainbow/steelhead in the American is puzzling, especially in light of their relative abundance in the neighboring Bumping River.

The American River originates at the foot of Chinook Pass at the confluence of the Rainier Fork and the Dewey Lake Fork, and flows approximately 24.5 miles to its confluence with the Bumping River. The river is bordered on north by the Norse Peak Wilderness Area, and the South by the William O. Douglas Wilderness Area, and is virtually pristine. Most of the river between Mesatchee Creek (RM 15.8) and the origin is flows through a wide, marshy floodplain in a multitude of small channels conducting flow around a series of beaver dams. Side channels are common above RM 5, as are wet meadows. The river enters a narrow gorge above Union Creek, at RM 14, where it drops 100 feet in 400 yards in a series of cascades. These cascades may be a barrier to upstream migration at low flows (CBSP 1990, WDFW 1998). The American is considered routinely accessible to spring chinook as far as the Cascades, and occasionally accessible up to the beaver dam marsh just below Mesatchee Creek.

The mean gradient of the American River is 1.4%, although in the lower five miles the gradient considerably steeper (3-4%) and the river is filled with large boulders and large woody debris. Except for some bank damage at several campgrounds, the riparian corridor of the American River is pristine, consisting in most places of an overstory of old growth Douglas fir and an understory of willows and alder. Between RM 5 and the confluence of Mesatchee Creek, large woody debris is abundant as are deep, well-protected resting pools, and large gravel bars consisting of a high proportion of small gravels and generally less than 10% fines (CBSP 1990, WDFW 1998; J. Matthews, YN, personal communication, 2000). Above Mesatchee Creek, the substrate becomes primarily sand and, where beavers are active, mud. Some of the best spring chinook spawning and rearing habitat in the entire Yakima Subbasin is found in the American River between RM 5 and 15.8 (WDFW 1998).

Water quality is generally excellent in the American River (CBSP 1990) although and 23 excursions for water temperature were documented in the American River at RM 0.5 in the very hot years of 1992 and 1994.

The hydrograph of the American River is considered to be essentially natural. Mean monthly flows typically range from about 50 cfs in September to 650-700 cfs in May, although extreme low flow periods in recent years have been concentrated in the fall and winter months (October through January). In the drought years of the 1980's and the very dry years of 1992 and 1994, late fall/winter flows below 30 cfs were not uncommon. A peak flow of 2,857 cfs was observed in the American during the February flood of 1996. Production may be limited by naturally low flows in the summer fall and winter combined with extremely cold and long winters.

A recent EDT simulation indicated that the American River had a preservation value for spring chinook far larger than any other portion of the Yakima subbasin, and was easily the most productive single reach in the subbasin.

Ahtanum Creek

Ahtanum Creek is a right bank tributary to the lower Yakima River, entering at RM 106.9. Ahtanum Creek is 46 miles in length, including the NF (CBSP 1990). The NF and SF merge to form Ahtanum Creek at RM 23.1; the NF is 23 miles long, and the SF is 15 miles long. (CBSP 1990). Salmonids are present in at least 50 miles of SF, MF and NF Ahtanum and tributaries (DNR. Feb 2001. Ahtanum Landscape Planning Area Map). The primary land use in the lower Ahtanum (downstream of Tampico) is agriculture (WDFW 1998). There is considerable housing and industrial development taking place along the lower mainstem. Ahtanum Creek supports Chinook, coho, steelhead, and bull trout, as well as rainbow trout, westslope cutthroat, whitefish and native non-salmonids (WDFW, 1998). The bull trout population (resident and upstream of RM 19.6) is geographically isolated due primarily to dewatering of the mainstem Ahtanum and the status is designated as critical (WDFW 1997b). Coho and steelhead spawn and rear in Ahtanum Creek, while juvenile spring chinook use the lower portion as rearing habitat. Except for passage and flow problems associated with water diversions from Tampico downstream, Ahtanum Creek would likely be a major steelhead producer (CBSP 1990).

Fish Access

Many miles of good to excellent habitat for steelhead, coho, and spring chinook are unused in Ahtanum Creek because of relatively easily correctable passage problems (CBSP 1990). The two major fish passage problems facing the Ahtanum are the fact that few of the ditches in the watershed are screened, and that the Upper Wapato Irrigation Project (WIP) diversion at RM 19.6 partially dewaters all downstream areas from July 10 through mid-October (CBSP 1990). Adult passage is typically only possible from some time in November (when flows resume due to runoff) through May (when irrigation diversions become substantial and spring runoff subsides. The irrigation diversion dams at upper and lower WIP, and Hatton Creek have been notched for fish passage.

Concrete dams formerly diverted water into side channels named Hatton Creek (RM 18.2) and Bachelor Creek (RM 18.9, which reentered Ahtanum Creek downstream at RM 8.5. The old Hatton diversion no longer exists, but Bachelor Creek still reenters Ahtanum Creek at RM 8.5. In 1994 the Hatton and Bachelor diversions were merged and the new Batchelor-Hatton Creek diversion was screened. Water for the old Hatton channel is diverted below and from the new Bachelor-Hatton Creek channel. Irrigation water is diverted at the new diversion from April l5 to October 15th if available, but WIP generally diverts 100% of the flow after July 15, consistent with a court order. At that time the Batchelor-Hatton channels both become dewatered. The Batchelor-Hatton diversion serves as irrigation conduits for the Ahtanum Irrigation District. Numerous pumps and gravity ditches divert water from these creeks during the irrigation season

The Upper Wapato Irrigation Project facility at RM 19.6 diverts all or most of the stream flow from July 10 through mid-October, drying up the natural streambed downstream for 7-8 miles, precluding adult salmonid access to high quality spawning habitat upstream (WDFW 1998, CBSP 1990). The lower Wapato Irrigation Project diversion (RM 9.8, near Ahtanum village) is a total passage barrier to migrating adult salmonids (CBSP 1990). during the summer when the stream channel is dewatered. WIP reduced water diversion at least temporarily in 2000 due to steelhead ESA concerns, but this fish passage issue has not been resolved.

There are numerous unscreened diversions on Ahtanum Creek (CBSP, 1990) and numerous unscreened pumps. There are two diversions on the NF; the John Cox diversion (~13 cfs) is located at RM 3, and the Shaw-Knox ditch (~2 cfs) is located at RM 2. A screen was constructed and became operational in 1999 at the John-Cox Ditch. There is at least one unscreened diversion (~2 cfs) on SF Ahtanum at RM 3 (CBSP 1990).

Floodplain Modifications

Waters of the lower Ahtanum are heavily diverted, diked, and straightened (WDFW 1998).

Channel Condition

The gradient in the lower 8-9 miles is slight to moderate, and bank sloughing from overgrazing has caused deposition of large amounts of sand and mud (CBSP 1990). The selective removal of large diameter trees has affected the habitat quality in the Ahtanum watershed. These management-related activities have affected sediment input rates, channel-stabilizing large woody debris recruitment rates, and instream cover. Debris flow and dam break floods have occurred the Ahtanum and have most often related to extreme runoff events. Most Ahtanum moderate gradient and steep mainstem channels are confined or moderately confined, a configuration that does not provide adequate floodplain, side-channel and low-gradient habitat. MF and lower NF Ahtanum have low abundance of large woody debris (Dominguez, 1997).

Substrate Condition

The gradient in the lower 8-9 miles is slight to moderate, and bank sloughing from overgrazing has caused the deposition of a large amount of sand and mud (CBSP 1990). Bambrick and Mathews (1990, unpublished report) indicated that moderate to high levels of silt (~15-25% particle size <.85mm) were found in some sample reaches of the upper NF and SF, with the highest stream average in the SF Ahtanum at 25% silt. In 1991 Matthews (unpublished data) collected McNeil gravel samples in the MF, SF, Ahtanum Creeks and found that these tributaries ranged between 20-25% silt, a concern for salmonid habitat. Dominguez (1997) concluded that poor instream habitat heterogeneity and excessive road-related sediment input indicate a fine sediment input problem.

Although a 1996 flood event was a gravel-cleaning event, chronic sediment input from surface and bank erosion due to road encroachment may have minimized or negated any gravel cleansing effects (Dominguez, 1997).

Riparian Condition

Good riparian vegetation in the lower 8-9 miles is patchily distributed, with much of the riparian zone severely impacted by grazing (CBSP 1990). Riparian condition is poor/fair downstream of Tampico, and good/excellent in the 10-20 miles of tributaries upstream of Tampico (CBSP 1990, WDFW 1998). The numerous homes and cabins in close proximity to the creek have resulted in significant impacts to bank stability and riparian vegetation. The NF in the vicinity of Tampico park area has been largely denuded on riparian vegetation and the channel was significant channelized after the flood of 1996 (Perry Harvester, Personal Communication, Feb. 2001). Upstream of Tampico, on both the NF and SF, sedimentation and reduced riparian vegetative cover from cattle grazing, logging, and associated road networks in close proximity to riparian areas are the primary concerns (WDFW 1998). Direct trampling of bulltrout redds by cattle occurs in the NF (WDFW 1998). Excessive off-road vehicle use within riparian corridors is also a problem in some areas on the NF (WDFW 1998).

Water Quality

Water quality is fair downstream of Tampico, and good upstream (including the NF) (WDFW 1998). Water quality is good in the 10-20 miles of tributary stream upstream of Tampico (CBSP 1990).

Water Quantity

The Upper Wapato Irrigation Project facility at RM 19.6 diverts all or most of the stream flow from July 10 through mid-October, drying up the natural streambed downstream for 7-8 miles (to approximately RM 12) after the first week of August (WDFW 1998, CBSP 1990). Discharge is substantial downstream of the WIP diversions from mid-October through July (outside the irrigation season)(CBSP 1990). At RM 12, groundwater and irrigation returns recharge the stream, even during the worst period of dewatering. The resulting flow of 5-10 cfs persists to the mouth (CBSP 1990). Instream flows upstream of Tampico and in the NF are rated as good (WDFW 1998).

Currently, there is a proposal to build a reservoir in Pine Hollow. Water would be diverted at the John Cox diversion on the North Fork Ahtanum. Waters diverted would be used to supplement irrigation from mid-summer through the fall when flows are low. A major component of the proposal is to use a portion of the diverted water for instream flows when it is needed for fish. Study efforts are underway to determine if the reservoir can provide benefits for fish and wildlife.

Satus Creek

Location and Topography

Satus Creek basin is located in south-central Washington. Within the southeast portion of the Yakima Indian Reservation. Satus Creek enters the Yakima River at rivermile 69.6. It is bounded on the north by Toppenish Ridge and by Horse Heaven Hills on the south. The western headwaters are contained by the Simcoe Range, while the eastern boundary is defined by the Yakima River. Satus Creek basin covers an area of 710 square-miles and is approximately 40 miles in length by 20 miles in width. The basin dips to the northeast, towards the Yakima River. The maximum elevation occurs in the southwest portion of the basin, at about 5,800 ft at Potato Butte. The lowlands along the eastern edge of the basin average 650 ft above sea level. The basin's topography accounts for the northwest orientation of the drainage pattern. Its major tributaries include Mule Dry Creek (18 miles), Dry Creek (39 miles), Logy Creek (14 miles), and Kusshi Creek (11 miles).

In terms of salmonids, the Satus basin primarily supports a steelhead population, though historically spring chinook spawned and reared in portions of the basin.

Climate

Satus Creek basin is characterized by a climatic gradient from midlatitude desert steppe to mountain or highlands. The annual amount of precipitation decreases rapidly moving eastward from the Cascade crest. Average annual precipitation ranges from about 35 inches along the crest of the Simcoe Mountains, in the southwest corner of the basin, to less than 10 inches in the northeastern corner of the basin. The greatest period of precipitation occurs October through March, where 84 percent and 66 percent of the annual precipitation occurs in the highlands and lowlands respectively (Mundorff et. al., 1977). Mean precipitation from June through August is only 0.81 inches for the basin. Snowfall occurring along the Simcoe Mountain Range normally remains until May or early June. However, snowfall occurring in the lowlands and lower uplands, below ~2,500 ft is often melted during January or February by warm chinook winds.

Mean monthly air temperatures in the lowlands of the basin range from a January low of -1.0o C to a high of 22.3^{o} C in July. In the lowlands during the summer daily temperature extremes can range from 40.5^{o} C to 4.5^{o} C. In the winter daily temperature extremes can range from 10.0^{o} C to -25.0^{o} C.

Geology and General Stream Flow Patterns

The geological foundations of the subbasins- Dry, Kusshi, Logy and Mule Dry investigated are different. These differences account for variations in both temporal and spatial flow conditions observed in the tributaries within the basin. Of the four tributaries investigated in this study, Dry, Kusshi and Mule Dry Creeks become intermittent by late spring or summer, while Logy Creek maintains permanent year-round stream flow. The geologic and climatic differences between the intermittent tributary watersheds (Dry, Kusshi and Mule Dry) and the Logy Creek watershed are largely responsible for differences seen in annual stream flow patterns between the two watershed types. Overlying the Yakima Basalt Subgroup in the western upland area of the basin is the Simcoe Mountains Basalt layer. This particular basalt layer is relatively permeable and is able to store large amounts of precipitation (Mundorff et. al., 1977). The permeable Simcoe Mountains Basalt layer coincides geographically with the region of the basin that receives the greatest annual precipitation. This allows for large quantities of water to be stored, which is gradually released into the stream as surface or sub-surface flow.

The permanent annual stream flow in Logy Creek is explained by the large portion (63%) of the entire watershed that lies within the Simcoe Mountains Basalt region. Second, over half (52%) of the entire watershed is located in the western upland region, which receives the greatest amount of precipitation. In contrast, only 25% of the entire Dry Creek watershed lies within the Simcoe Mountains Basalt region and within the area of greatest precipitation in the western highland region. Furthermore, greater alluvial deposition (which is very porous) as a result of lower stream gradient and greater channel width in Dry Creek relative to Logy Creek, allows flow to percolate into the substrate, resulting in subsurface flow at reduced stream flows. This is most evident in Dry Creek downstream to the "elbow" at rivermile 13, which becomes intermittent in late spring. Kusshi and Mule Dry Creek watersheds are both located outside the Simcoe Mountains Basalt region and receive much less annual precipitation than either Dry or Logy Creek watersheds. Both watersheds also have alluvial deposition and wide channel width (especially Mule Dry Creek) similar to that in Dry Creek. Consequently, both Kusshi and Mule Dry Creeks become intermittent too.

Fish Access

Generally speaking fish access for both adult and juvenile steelhead passage. There is a need to address undersized culvert(s) and excessive channel braiding in lower Logy Creek at Sheep Camp. Severe, natural low flows in lower Mule Dry, Dry and Kusshi creeks, in part a result of upslope land use practices, in the late spring and summer impact both spawner, post-emergent fry and parr up/down movement, and ultimately survival.

Floodplain Modifications

Generally speaking floodplains within the Satus basin have remained intact, in that little diking has taken place. The biggest impact in terms of confining the floodway has occurred from the construction of Highway 97 and the Lakebeds Road in upper Satus Creek. Large portions of the Lakebeds Road and associated diking have been removed within the past five years.

Channel Condition

The lower six miles of Satus Creek are slow moving with a mud/sand streambed and a few isolated riffles. The remainder of the watershed contains considerable spawning area and substrate for steelhead. Stream gradient is 0.2-0.3% in the lower 37 miles of Satus Creek, increasing to 1-2% upstream (CBSP 1990).

Large portions of the basin has degraded channel conditions for a variety of reasons, including- grazing (upslope and within the riparian zone), road building, timber harvest, and agricultural practices (lower Satus primarily), and destructive flood events (exacerbated by prior land use practices). In general these occur in the lower and mid portions of Mule-Dry, Satus, Dry (lower only), Logy (lower only) and Kusshi (lower only) creeks. Specific problems are bank sloughing (i.e. lower Satus), lack of riparian cover, and unstable channels. The upper portions of Dry, Logy and Kusshi creeks are generally in good to excellent conditions.

Substrate Condition

Substrate condition as measured by interstitial fines is highly variable. Mule-Dry Creek has excessive fines and bedload movement during flood events. Logy Creek on a whole is generally good with the exception of the lower reach in the Sheep Camp area. Dry Creek has excessive fines in the lower portion, and improves significantly in the upper reaches. Kusshi Creek has significant bedload movement and the channel is highly unstable. Fines vary within Kusshi Creek, and substrate size is generally large due past flood events scouring out the smaller cobble sizes. Satus Creek has excessive fines throughout its course, but improves somewhat in the upper reaches above High Bridge.

Riparian Condition

Fairly large areas of the Satus watershed have suffered riparian damage from "unrestricted streamside grazing" (CBSP 1990). This term is used instead of overgrazing because most of the reservation land along Satus Creek is managed as open range. The numbers of cattle on the reservation are not actually excessive, but because of the lack of water and shade, and the lack of streamside fencing, the cattle that are present spend virtually all of their time in and around streams (CBSP 1990). Riparian damage is uniformly distributed, with much of the damage consisting primarily of bank sloughing; many impacted areas still support fair numbers of large trees that often provide adequate shading. These areas have been prioritized by productive potential and need for restoration (in descending order of importance) as follows (CBSP 1990):

- Satus Creek from Dry Creek (RM 18.7) to High Bridge (RM 30.1)
- Dry Creek, from the mouth to 3 miles upstream of Elbow Rd. crossing (~RM 27)
- Logy Creek, mouth to the first crossing upstream of Sheep Camp (~RM 2.5)
- The entire Mule Dry Creek drainage
- Lower Satus Creek, mouth to Mule Dry Creek (RM 8.5)

Water Quality/Water Quantity

Water quality throughout the Satus basin is generally considered to be good. The only exception might be lower Satus (below Plank Road) where the creek begins to flow through agricultural lands. Most of the watershed is undeveloped- this is not exposed to agricultural related chemicals being applied to the landscape.

With the exception of Logy Creek, all the Satus tributaries would be more productive if summer flows were higher (CBSP 1990). Mule Dry, Dry, Kusshi, and Wilson Charley creeks normally become intermittent in their lower downstream reaches beginning in late-May. Instream flows are in Satus Creek fair/good, except for low summer flows, particularly from RM 24-30, which limit the productivity of Satus Creek (CBSP 1990, WDFW 1998). Intermittent instream flows in these aforementioned reaches have been exacerbated by excessive bedload being carried downstream from headwater reaches and deposited in these alluvial, low gradient reaches. This has resulted in surface flows becoming subsurface flows as stream discharge decreases.

Water temperatures beginning in the late spring and persisting through the summer are often sublethal (approximately 26^{o}C) in the lower Satus and Dry creeks. What little surface flow that remains in Mule Dry is of optimal temperature (15-20^{o}C) in the shaded reaches. This is due to the cooling effect of the subsurface flow. Similarly, Logy Creek has optimal temperatures in the summer, as well as, good surface flow. This is due to the large groundwater influence in its headwaters from water stored in the fractured basalt layer. Kusshi Creek has reasonable water temperatures for steelhead throughout its course where surface flow persists. Satus Creek upstream to Logy Creek has reasonable water temperatures, which may occasionally become sublethal in the middle reaches during the summer.

Toppenish Creek

Toppenish Creek is a right bank tributary to the lower Yakima River, entering at RM 80.4. This 625 mi^2 watershed is located entirely within the Yakama Indian Reservation. Toppenish Creek is 70 miles long, with the major tributaries including Simcoe Creek (18.9 miles), NF Simcoe (13.9 miles), SF Simcoe (12.8 miles), NF Toppenish Creek (18 miles), and SF Toppenish (6 miles)(CBSP 1990). The upper half of the drainage -- above about RM 48 on Toppenish Creek and the entirety of the North and South Forks of Simcoe Creek -- flows out of heavily forested mountains. The canyon through which upper Toppenish Creek flows is several hundred feet deep and often precipitous. The lower half of the drainage flows through arid shrub-steppe. Toppenish Creek and its tributaries in the forested zone are fast-flowing, pocketwater streams with gradients in accessible reaches ranging from 1.7 to over 3 percent. The lower half of the creek is much slower, with a gradient of 0.1% or less except for the reaches immediately below the canyons.

The historical Toppenish Creek was one of the most complex drainages in the entire Yakima Subbasin. The 1909 Indian Irrigation Service map presented in the discussion of the lower Yakima mainstem illustrates that Toppenish Creek and the mainstem Yakima were commingled over approximately the lower 20 miles of what is now called Toppenish Creek. The discussion of the aquatic ecology of the Wapato alluvial reach presented in the Lower Yakima section therefore applies equally to lower Toppenish Creek. Annual flooding, cool baseflows, high habitat complexity associated with dense riparian vegetation and massive accumulations of large woody debris – all of these characteristics were as applicable to lower Toppenish Creek as to the mainstem Yakima in this area. An additional layer of complexity was supplied by upper Toppenish Creek, inside the canyon. Although not so massively complex as the Wapato alluvial reach, the creek in Toppenish Canyon flowed through multiple anastomosing channels primarily because of a massive quantity of large woody debris trapped equally massive gravel bars, creating stable islands and diverting water into side channels and the hyporheic aquifer, thereby creating springbrooks downstream. From headwaters to the lowermost point of its commingling with the mainstem Yakima, Toppenish Creek at one point or another provided virtually the entire spectrum of salmonid habitat types: steep, cold, pocketwater/step-pools in the Simcoe forks and upper Yakima tributaries; fast, complex pool/riffle/run habitat in mainstem Toppenish Creek in the canyon; and slow, pool/glide/riffle habitat in the lower reaches.

Except for upper Toppenish Creek above RM 48, the Toppenish Creek of today bears little resemblance to the historical creek. As described in the Lower Yakima Mainstem section, the Wapato alluvial anastomosis has been obliterated; therefore the “main river” character of lower Toppenish Creek has been utterly lost. In addition, almost all of the wetlands that surrounded the historical creek have all been drained and the Wapato Irrigation Project has transformed lower Toppenish into an irrigation ditch. Warm, turbid water from various lateral and drains enters the drainage at a number of points and is diverted further downstream, with a net effect of increasing sediment deposition and water temperature and decreasing base flows to such a degree that various side channels in the lower creek are routinely dewatered. In addition, another diversion, the Toppenish Lateral Canal at RM 44.2, dewaters the upper creek from mid–June until the fall rains come, and a number of smaller diversions on Simcoe Creek have nearly as severe an impact. Finally, a host of poorly maintained diversions for waterfowl ponds on the lower creek are unscreened, almost certainly resulting in the entrainment and eventual stranding of smolts.

Nevertheless, Toppenish Creek is still one of the major steelhead producers in the subbasin, and may in fact be the biggest steelhead producer. It was not until 1998 that the Yakama Nation found a route into the upper portions of the Toppenish Creek Canyon and began conducting steelhead spawner surveys there. Moreover, prior to 1998, spawner surveys in the upper creek were not thought truly necessary, because the topography from maps suggested a very narrow and fast stream that in all likelihood was inaccessible due to landslides and/or debris jams. When the upper reaches were finally walked, a very different picture emerged – the picture sketched above of a complex, multi-channel, pool/run/riffle stream spread over the entire valley floor by massive logjams.

Toppenish Creek above the South Fork probably represents the best steelhead habitat in the Yakima Subbasin. Base flows exceeding 15 CFS are sufficient to keep pools and riffles watered up. Large woody debris is plentiful, as are the related pools and gravel bars. Spring snowmelt and runoff generally include flows sufficient to redistribute the substrate as well as capture and move woody debris. Moving, sorting and depositing of cobble, gravel and large woody debris has provided a multitude of gravel bars, pools and riffles that include numerous sites presumably suitable for spawning. Upper Toppenish Creek is without a doubt a dynamic and valuable part of the Yakima Subbasin ecosystem, especially for steelhead. Moreover, recent redd counts that for the first time included upper Toppenish have equaled or exceeded redd counts in Satus Creek. If this trend continues to be observed, it will be necessary to re-think the distribution of steelhead in the Yakima Subbasin. Steelhead escapement into the Naches drainage must be estimated by subtracting the sum of Satus, Toppenish and upper Yakima counts from total counts at Prosser Dam (since it is impossible either to count steelhead adults or steelhead redds in the Naches drainage). If Toppenish counts must be revised upward, Naches counts will have to be correspondingly reduced. A final illustration of the potential significance of steelhead production in Toppenish Creek is the fact that about 35,000 steelhead smolts were estimated to have migrated out of Toppenish Creek in 2000. The total steelhead outmigration estimated at Chandler was only 41,361.

Historically, there is no reason to believe that Toppenish Creek did not support all salmonid species found in the subbasin save sockeye. Currently, Toppenish Creek supports steelhead spawning and rearing roughly above the confluence with Simcoe Creek, and small populations of cutthroat trout in the tributaries of the upper creek. Conclusive evidence of the existence of resident rainbow trout in Toppenish Creek has not yet been found: the oldest specimens of <u>O. mykiss</u> found to date were 2+ and 3+ fish collected in a screw trap that morphologically clearly appeared to be smolts. <u>O. mykiss</u> of age 3+ or greater that did not appear to be smolts have never been observed.

The current distribution of steelhead redds in Toppenish Creek was described in the fish status section and need not be repeated here. Here it is only necessary to add that virtually all juvenile rearing occurs in the same general areas as spawning, partly because upper Toppenish Creek is dewatered by an irrigation diversion for over half the year, and partly because water temperatures in lower Toppenish Creek have become too high.

The following section will describe the factors that have changed the historical Toppenish creek to the system we see today. In this discussion, the destruction of the Wapato alluvial anastomosis will be assumed. The other factors that have affected the stream, the first five of which are directly attributable to WIP, are as follows:

- Dewatered reaches
- Excessive summer temperatures in middle and lower Toppenish Creek
- Fish passage problems
- Poor substrate in Toppenish and Simcoe creeks
- Excessive velocities and depths in Toppenish Creek
- Hunting club waterfowl ponds
- Riparian degradation

Fish Access and Passage

Toppenish Creek and the WIP major irrigation return flow ditches are so extensive and intertwined, that they are best considered as a unit in lower Toppenish Creek. The WIP Toppenish Lateral Canal diversion (RM 44.2) dries up 6.8 miles of Toppenish Creek from mid-June to mid-December. Other fish passage problems include unscreened diversions on the Toppenish/Marion drain flood control ditch (RM 19), and braids on the middle portion of Toppenish Creek where flows go subsurface and strand juveniles (WDFW 1998). There are at least eight braids on Toppenish Creek from approximately RM 42.5 downstream to about half a mile upstream of Slayton Road (RM 6)(CBSP 1990). Many of these braids dry up every spring after the high water period, and all of them dry up occasionally, constituting a stranding hazard for juvenile salmonids. Five of the braids branch off Toppenish Creek downstream of the Toppenish Creek Pump diversion, with stranding of smolts attributable to WIP withdrawals that result in dewatering, or dewatering earlier than would otherwise occur. One of the braids feeds numerous small, unscreened diversions, resulting in entrainment hazards even in exceptionally high water years when none of the braids are dewatered (CBSP 1990).

There are approximately 20 private waterfowl hunting clubs and one large federal waterfowl refuge on Toppenish Creek, almost all of which fill their hunting ponds by erecting small dams on Toppenish Creek (CBSP 1990). This results in 30-40 small gun club diversions on middle and lower Toppenish Creek, which are constructed in mid-October, and are present at least through the end of the hunting season in January (many are frozen in place at the end of the hunting season and not actually removed until after high water in late-May or June). These diversions are not screened, and divert salmonids into the ponds. Although most of the diverted water is ultimately returned to the creek, the return path may be tortuous, including virtually impenetrable sections of dense vegetation and brush. The potential for smolt loss through entrainment and stranding in the gun club ponds is obvious. Although much of the dense tules and reedgrass have been removed from the Toppenish Wildlife Refuge ponds, entrained smolts likely become disoriented in the 9-10 miles of intricately interconnecting channels on the refuge, eventually residualizing or becoming stranded. However, the collective entrainment hazard posed by the private gun club diversions and ponds in much greater (CBSP 1990).

An illustration of the collective hazards posed to outmigrating smolts by these diversions is found in the survival of 25,000 Yakima-stock steelhead smolts released at the Toppenish lateral Canal in April of 1989. The survival over the 77 miles from the release point to the Chandler smolt trap (44 miles of Toppenish creek and 33 miles of the lower Yakima) was only 10%. This compares with an average survival of 25-30% for Skamania stock hatchery steelhead smolts released at Nelson Springs (Naches RM 3.3), 72.5 miles above the Chandler smolt trap.

The South Fork feeder canal is located on the South Fork of Simcoe Creek, 0.1 mile upstream of the confluence with North Fork (CBSP 1990). There is no diversion dam, and approximately half of the flow enters the diversion ditch. Most of the winter and spring ditch flow appears to return to Simcoe Creek, some through a bypass/washout about 0.1 mile down the ditch, and the rest after sheetflow over 40-80 acres of pasture. Neither this ditch, nor the Smartlowit Ditch (Simcoe RM 16.9), the Hubbard ditch (about 100 yards upstream of the Smartlowit diversion) nor the Miller ditch about (Simcoe RM 5.1) is screened, and all are presumed to entrain smolts.

There is a dam on lower Agency Creek (a Simcoe Creek tributary, confluence at Simcoe RM 9.5) at the Jen Weld Mill in White Swan that poses a passage problem at low flows. However, much of the time adult steelhead are able to negotiate it as numerous redds and live spawners have been observed in Agency Creek in recent years.

Floodplain modifications

Most of the land surrounding Simcoe Creek and virtually all of the land surrounding Toppenish Creek downstream from the Simcoe confluence has been drained of historical wetlands, side channels and slough, cleared, and converted to pasture, hop fields or row crops.

Channel Condition

The channel in almost the entire reach from the WIP Lateral Canal dam (RM 44.2) downstream to Pom Pom Rd. (RM 38.9) has been relocated, channelized, and diked (CBSP 1990), eliminating virtually all normal floodplain function in this reach. The resulting large, highly-fractured bed material within the channelized section allows considerable subsurface flow. YN personnel have observed that flows exceeding 20 cfs below the Lateral Canal go subsurface within two miles of the dam.

The channel from the Simcoe confluence (RM 32.7) downstream to the Toppenish Creek Pump diversion (RM 26.5) appears to have been deepened and straightened, although historical verification has not been found (CBSP 1990). Consequently, almost half of this reach consists of “runs”, with velocities of 3-4 feet/second (August 1989), with the remainder consisting of glides and pools having velocities of ~1 foot/second. Through most of the reach, velocity and depth are excessive for steelhead fry, particularly given the lack of large woody debris or boulders that would provide habitat diversity (CBSP 1990).

Overgrazing has caused extensive bank failure along most of Simcoe Creek.

Substrate Condition

The quality of substrate in Toppenish Creek from the Simcoe Creek confluence (RM 32.7) downstream to the Satus II diversion (RM 31.5) ranges from poor to extremely poor. Except for some areas in the upper portion of Toppenish Creek, where the streambed is composed almost entirely of clay, the problem consists of heavy deposition of fine sediments and organic silts (CBSP 1990). No rocks or gravel are visible from the pump diversion to the Satus II diversion; the bottom is covered with several inches to a foot or more of mud. Gravel and cobble are visible in the uppermost portion of the affected area, as well as below the Satus II diversion, but even there the substrate is fairly heavily embedded with fine sediment. The only area in this reach with substrate remotely approaching spawning quality is Snake Creek, a 3.5 mile long braid (CBSP 1990). Although the large quantity of suspended sediment in WIP irrigation return flows contribute to the substrate problem, irrigation is not wholly to blame; numerous small diversion dams and widespread riparian degradation probably play a role of equal importance (CBSP 1990). Nevertheless, substrate conditions would benefit from elimination of the discharge of tens of thousands of tons of sediments from drains such as Mud Lake Drain.

The waterfowl pond diversions on lower Toppenish Creek likely exacerbate the problem of accumulation of fine sediment in the substrate by creating over 30 small impoundments in the channel through much of the high water period of fall and winter, and a somewhat smaller number through the entire annual period of high water. Some long-time residents of the Toppenish watershed recall that 40-50 years ago, prior to the establishment of most of the gun clubs, middle Toppenish Creek contained gravelly riffles (CBSP 1990). The prolonged slowing of flows during the high water season likely exacerbates the fine sediment problem in middle and lower Toppenish Creek (CBSP 1990).

Substrate condition is excellent in the uppermost upper Toppenish Creek, as well as NF and SF Toppenish creeks, with abundant gravel of very high quality (CBSP 1990, WDFW 1998).

Dominant particle size of the substrate in Simcoe Creek is good, but sedimentation is heavy. (WDFW 1998). The quality of substrate in Simcoe Creek ranges from poor to extremely poor from the mouth to Olney Flat Drain (RM 1.0)(CBSP 1990). Substrate size and sedimentation in NF Simcoe are good (WDFW 1998). Substrate condition is good in Agency Creek, with sedimentation of gravels rated fair (WDFW 1998).

Riparian Condition

Degraded riparian condition in the middle and lower portions of Toppenish Creek exacerbate the problem of excessive water temperature (CBSP 1990). Riparian vegetation is generally absent in the channelized/diked reach from the WIP Lateral Canal dam downstream to Pom Pom Rd. (CBSP 1990). The middle and lower portions of Toppenish creek have many small, fenced, private pastures. Although patches of very dense riparian vegetation exist downstream, they are interspersed with larger areas (primarily pasture) with little or no vegetation, resulting in few reaches with extensive shade (CBSP 1990). There has not been an exhaustive riparian inventory in the Toppenish Creek watershed. However, the areas of worst damage, in decreasing order of significance to salmonids (Yakima Nation Fisheries personnel, as cited in CBSP 1990) are:

- Toppenish Creek from SR 22 (RM 3.3) to the Simcoe confluence (RM 32.7)
- Toppenish Creek from Pom Pom Rd. (RM 38.9) to the Toppenish Lateral Canal (RM 44.2)
- Toppenish Creek from the Toppenish Lateral Canal to the mouth of the NF (RM 55.4)

Part of the problem with the 2 miles above the lateral diversion is the diking and road building that was done which effectively confined and straightened the creek.

Riparian condition is excellent in upper Toppenish Creek, as well as in NF and SF Toppenish Creeks, except for the stretch of several miles just upstream of the WIP diversion (CBSP 1990).

Simcoe Creek has many small, fenced, private pastures. Although there are patches of very dense riparian vegetation, they are interspersed with larger areas (primarily pasture) with little or no vegetation, resulting in few reaches with extensive shade (CBSP 1990). There has not been an exhaustive riparian inventory in the Toppenish Creek watershed. However, the area of worst damage on Simcoe Creek is from the mouth to Wahtum Creek (RM 14.4)(Yakima Nation Fisheries personnel, as cited in CBSP 1990). This reach rates as the second worst riparian impact to salmonids in the entirety of the Toppenish Creek watershed. Riparian conditions on the forks are good, although there are some areas impacted by grazing. Riparian condition in Agency Creek is poor in the lower part and good upstream (WDFW 1998).

Water Quality

Water temperatures in Toppenish Creek, from the confluence of Simcoe Creek (RM 32.7) to the mouth, are excessive for salmonid rearing, and may occasionally be lethal (CBSP 1990, WDFW 1998). Instantaneous observations (most within a couple hours of noon) indicate that the mean temperature in July and August in this reach is 66-68^{o}F (19-20^{o}C); maximum temperatures observed have been as high as 85^{o}F (31^{o}C) just below the Satus II diversion (RM 26.5). Diel fluctuations are quite large -- 27^{o}F (15^{o}C) near the Simcoe confluence (CBSP 1990). The median diel temperature (79^{o}F, 26^{o}C) in this portion of Toppenish Creek exceeds the temperature at which steelhead populations lose biomass (23^{o}C) by 3^o C(CBSP 1990). More importantly, it may not be possible for steelhead to survive at all in much of this reach, as the upper incipient lethal temperature for steelhead is about 26^{o}C. The rare steelhead found in lower Toppenish creek in the summer are likely residing only in localized thermal refuges, such as spring seeps (CBSP 1990).

As is the case with the Lower Mainstem Yakima, there are multiple causes to the thermal pollution problem in lower Toppenish Creek, the elimination of annual spring flooding, the draining of wetlands and riparian degradation being three of the more important factors. Another problem is the large volume of warm irrigation water routed down Simcoe and Toppenish creek to the Toppenish Creek Pump and Satus II diversions (CBSP 1990). This water, which comprises as much as 80-90% of the flows approaching the Toppenish Creek pump diversion, has mean summer temperatures ranging from 68-73^{o}F.

Water quality impairments have been documented in Toppenish Creek (Ecology 1998). Documented water quality excursions that may be consistent with CWA 303(d) listing criteria include fecal coliform, 4,4'-DDE, and Dieldrin. In addition single water quality excursions have been documented for DDT, 4,4'-DDD, and Parathion, which would not meet the 303(d) listing criteria. Nevertheless, Toppenish Creek is entirely within the boundaries of the Yakama Nation, does not fall under the jurisdiction of the state for water quality, and water quality excursions are not included on the State 303(d) list. Water quality impairments likely adversely impact juvenile and adult salmonids in Toppenish Creek, as well as in the Yakima River downstream of the mouth of the creek.

Water quality in upper Toppenish and in the forks of Simcoe Creek is rated as good (WDFW 1998).

Water quality in Simcoe Creek is fair, the main problem being excessive water temperature (WDFW 1998). Water quality in Agency Creek is good (WDFW 1998).

Water Quantity

As previously mentioned, the Toppenish Lateral Canal dewaters 6.8 miles of Toppenish Creek from mid-June through mid-December. Similarly, most of the flow of Simcoe Creek is diverted at the Simcoe Narrows diversion (Simcoe RM 13.9) from mid-June to mid-December (CBSP 1990), nearly drying up a 1.5-mile reach downstream to the outfall of the Toppenish Lateral Canal. Current and estimated historical mean monthly flows in Toppenish Creek below the Toppenish Lateral Canal are depicted in Figure 63. Figure 64 depicts current and estimated mean monthly historical flows at the mouth of Toppenish Creek. The impacts of water withdrawals in the spring and summer, as well as subsurface returns, are clearly seen here.

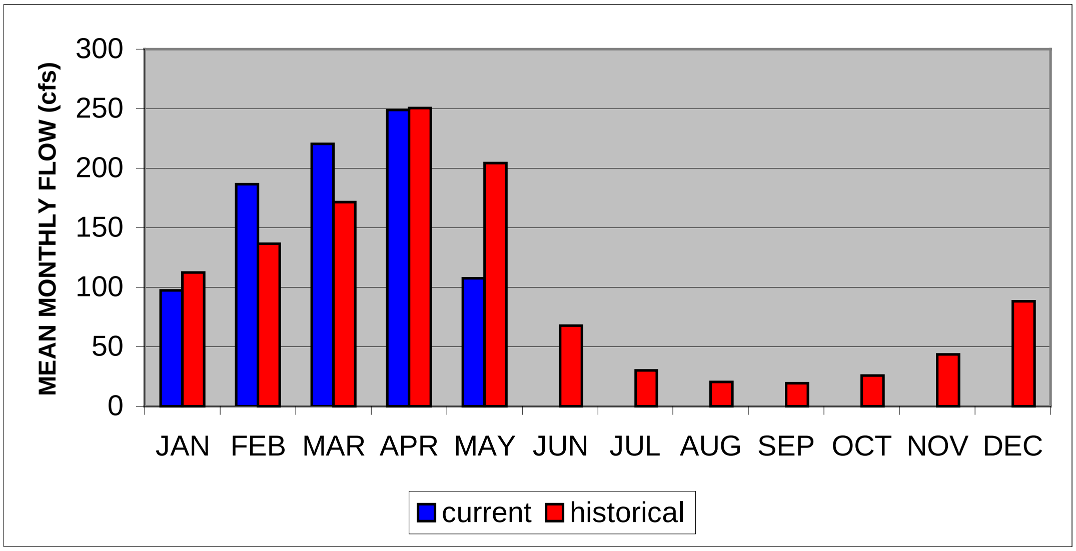


Figure 63. Current (1980*1991; WIP data) and estimated (HKM 1990) mean monthly flows in Toppenish Creek below the Simcoe Lateral Canal

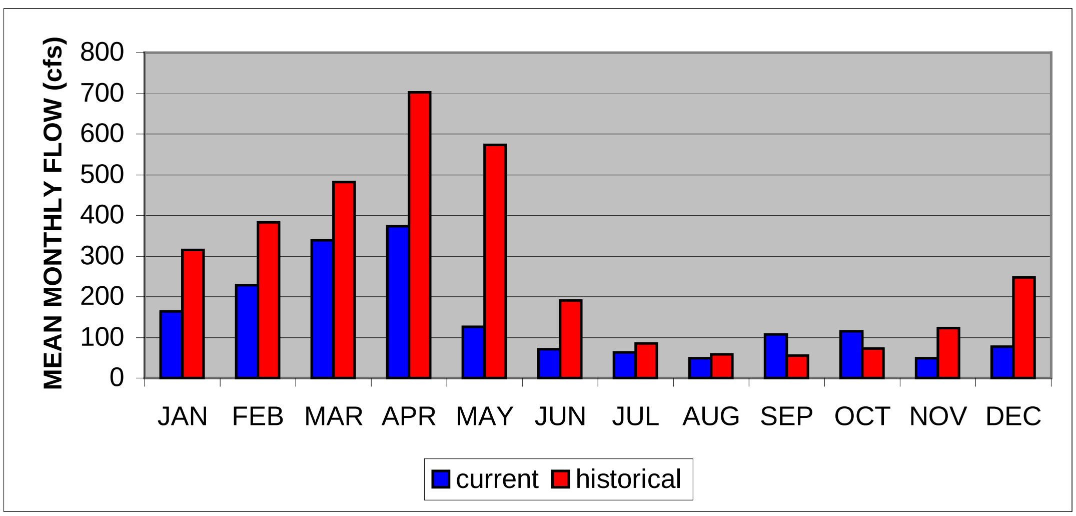


Figure 64. Current (1980-1991; WIP data) and estimated (HKM 1990) mean monthly flows in Toppenish Creek near the mouth

The Hoptowit diversion (~RM 1 of NF Simcoe) diverts most of the flow from the North Fork of Simcoe Creek, and contributes to the dewatering of the creek from the diversion to the confluence with the South Fork from mid-June to mid-December (CBSP 1990). Channel braiding exacerbates the instream flow problem, increasing both evaporative and seepage losses while simultaneously increasing temperature through insolation. The Hoptowit diversion also is unscreened, resulting in entrainment of virtually all outmigrating smolts (CBSP 1990, WDFW 1998). Instream flows in Agency Creek are rated as fair (WDFW 1998). Both Agency Creek and Wahtum Creek are perennial in their upper reaches, but often dry up near their mouths. It is unclear whether this is natural or anthropogenic, perhaps being caused by the many local wells lowering the water table (R. Evenson, YN, personal communication, 2001).

Lower Yakima

Historically the two alluvial portions of the lower Yakima supported all life stages of summer chinook, fall chinook, steelhead and coho, as well as the juvenile life stages of spring chinook. The importance of the Wapato alluvial reach to historical production was probably enormous. As is evident in Figure 65, the Wapato alluvial reach was about 30 miles long, up to five miles wide and extraordinarily complex. Except for channels in recently disturbed areas, most would have been bordered by dense growths of willows and the larger, older channels by cottonwoods. The accumulation of woody debris, recruited on site and from the upper basin, must have been enormous and was probably a major reason for the channel complexity in the first place. The benefits of large woody debris with respect to creation and maintenance of pools and gravel beds would have created ideal structural conditions for spawning and prespawning adults, and the discharge of spring runoff stored in the Toppenish/Yakima hyporheic aquifer and in various wetlands along Toppenish and Simcoe Creeks would have kept water temperature cool enough for juvenile rearing in the summer. A major proportion of the basin-wide production of chinook and coho salmon was probably attributable to this reach and, to a much lesser degree, its diminutive sister reach between RM 8 and 16. One significant difference between the Wapato and the lower alluvial reach is that the latter was not fringed by cottonwoods. Early explorers noted cottonwoods were not encountered below ~RM 40 (except in the Yakima delta), although willows and other brush was dense (Harner 2001).

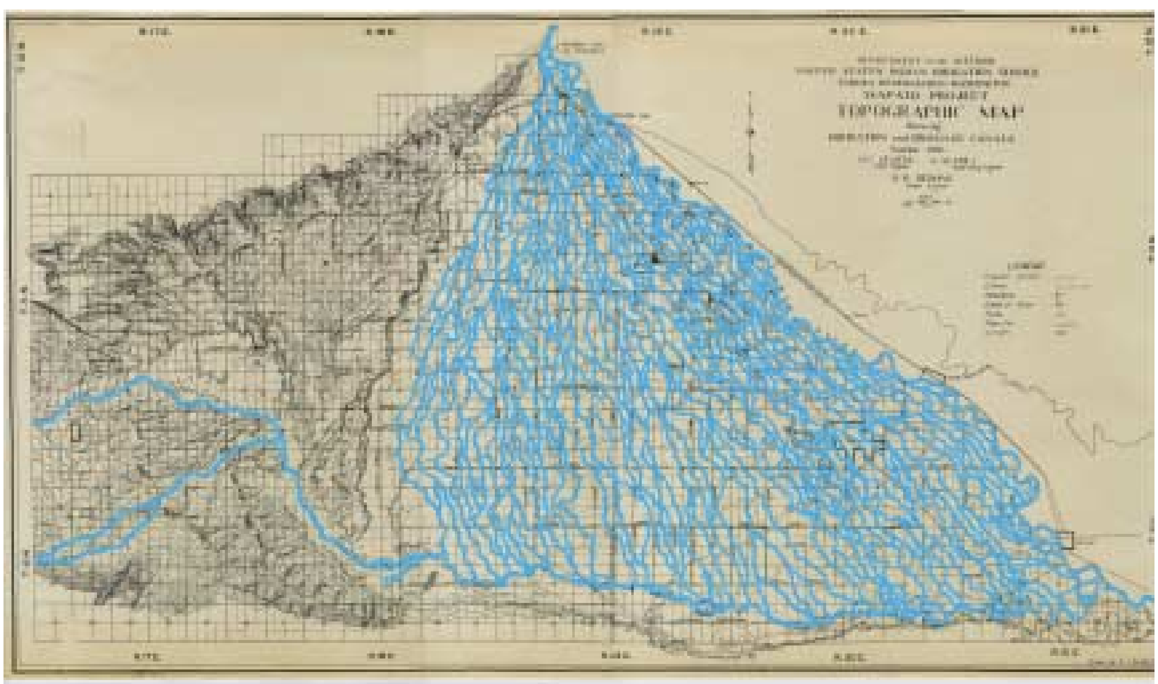


Figure 65. Indian Irrigation Service map of the Wapato alluvial reach in 1909 (map courtesy USBR Yakima Project). The tributary entering from the left is Toppenish Creek.

Wildlife Habitat

The subbasin contains a variety of habitat types, including mixed coniferous, deciduous, grassland/meadow, shrub-steppe, cliffs/canyons, riparian/wetland, riverine, alpine and agricultural. Habitat quality varies, but many habitats have been lost or degraded by past or present land use activities such as logging, agriculture, road building, hydropower development, invasion of non-native plants, and expansion of human development.

Development of agricultural land and construction and operation of associated facilities, combined with other development and urbanization changes in the basin, have altered numbers, diversity, and distribution of native wildlife species. Physical habitat, mobility, food supply, and interspecies interactions have been affected across a variety of habitat types.

Forested

Forests in the Yakima sub-basin can be roughly divided into dry and wet types. Dry forests, dominated by ponderosa pine, largely occur at lower elevations on private land, and have been heavily harvested for many years (USDA, ICBEMP 1997). Most large diameter Ponderosa pines in the Yakima sub basin have been harvested. A cooperative group of agency and private landowners (the Healthy Ponderosa Pine Working Group) was formed in 1999 to address this issue in eastern Washington,. An initial review of forest inventory on state lands indicates that high-density, large diameter ponderosa pine stands are now rare on the landscape (Crawford, WA DNR, 2000). These habitats, dominated by large diameter (>20" DBH) ponderosa are critical habitat for white-headed woodpeckers and flammulated owls, two candidate species for state listing in Washington. Modern forestry practices of clear cutting, snag-removal, fragmentation and even aged management have contributed to declines in white-headed woodpecker populations (Garret et al. 1996). The status of flammulated owls is poorly understood, with no formal assessment or survey in Washington completed. Conservation of species dependent on dry forests is an important, emerging conservation issue, particularly for white-headed woodpecker and flammulated owl.

Tree species present in wet types include Western hemlock, Douglas fir and grand fir. Dry forests are dominated by ponderosa pine, accompanied by Douglas fir. Spotted owl, varied thrush and flying squirrels are examples of wildlife in these forest types.

Late seral, or old growth forest of all types, are habitats of high value and particular concern in the Northwest. The high economic value of this timber has led to wide scale harvest and therefore reduction in acreage and quality of this habitat type. Remaining stands on private lands continue to be cut, and most unprotected stands will be cut in the next few years. The federal listing of the Northern spotted owl, an old forest dependent species, in 1994 bears out this situation

On the Cleman Mountain Unit of the Wenas Wildlife Area past timber harvest practices and relatively unrestricted vehicle use of numerous unimproved roads has resulted in establishment of major weed infestations along roadsides, log landing and other disturbed soil sites through the unit.

Timber has been intensively managed on the WDFW's Oak Creek wildlife area with timber rights on WDFW lands being held by Boise Cascade Corporation, and intermingled DNR lands being managed for commercial timber as well. Although intensive timber management can have a negligible negative impact to big game (depending on resulting road densities), habitat for forest dependent species has been degraded by repeated removals of the largest trees over multiple timber harvest entries.

Fringe/Transition

This important ecotonal habitat type between shrub steppe and forest is a widespread and important habitat for many species in the Yakima subbasin. It has particularly high wildlife species diversity, with representatives from shrub steppe and forest zones represented. Well-developed shrub components provide valuable habitat for wintering big game, particularly deer. Trees growing in this zone are often poorly formed and solitary, with significant use by raptors and migrating birds. Riparian vegetation in canyon bottoms and along springs and creeks offer valuable habitat for migratory songbirds and many other species. Reptiles are well represented here.

This habitat has suffered from removal of large, valuable trees, (particularly ponderosa pine), and over grazing. Agricultural and residential conversions are ongoing, leading to increasing conflicts between wintering big game and humans. Long-term protection of habitat in this zone will enable wintering big game and other species to flourish, and reduce human conflicts.

Winter Range

The Yakima subbasin River drainage is considered entirely within the eastside Cascades province. Winter conditions in this area tend to be colder with more frequent snow accumulation. Loss of big game winter range from development has impacted big game herds from historic levels due to loss of low elevation riparian and shrub habitat. During years of high snow accumulation (i.e. 1996) deer are frequently seen congregating in the lower elevations adjacent to agriculture lands. Current management of big game in the Yakima sub basin is primarily associated with land owned by the WDFW and the Washington DNR. Future protection of the Yakima deer and elk herds depends on management and protection of fringe habitats controlled by WDFW and private landowners. Future acquisitions of key parcels would help ensure the continued health of these herds.

Oregon White Oak *(Quercus garryana)*

Oregon white oak is Washington's only native oak. Although limited and declining, oaks and their associated floras comprise distinct woodland ecosystems. The various plant communities and stand age mixtures within oak forests provide valuable habitat that contributes to wildlife diversity statewide. In conjunction with other forest types, oak woodlands provide a mix of feeding, resting, and breeding habitat for many wildlife species. More than 200 vertebrate and a profusion of invertebrate species use Washington's oak woodlands. Some species occur in especially high densities, whereas others are not typically found in Washington (Larsen and Morgan 1998).

Oregon white oak is considered a state priority habitat that is determined to be of significance because it is used by an abundance of mammals, birds, reptiles and amphibians. Many invertebrates, including various moths, butterflies, gall wasps and spiders are found exclusively in association with this oak species. Oak/conifer associations provide contiguous aerial pathways for animals such as the state threatened western gray squirrel and they provide important roosting, nesting and feeding habitat for wild turkeys and other birds and mammals. Dead oaks and dead portions of live oaks harbor insect populations and provide nesting cavities. Acorns, oak leaves, fungi and insects provide food. Some birds, such as the Nashville warbler, exhibit unusually high breeding densities in oak. Oaks in Washington may play a critical role in the conservation of neotropical migrant birds that migrate through or nest in Oregon.

Oregon white oak stands in the subbasin are being lost and degraded by conversion to urban development and agricultural and range lands. Other factors that negatively affect white oak stands are fuelwood cutting, cattle grazing, and conifer encroachment caused by fire suppression (Larsen and Morgan 1998).

Riparian/Wetland

Riparian

The majority of terrestrial vertebrate species use riparian habitat for essential life activities and the density of wildlife in riparian areas is comparatively high to other habitat types. Since the arrival of settlers in the early 1800’s, 50 to 90% of riparian habitat in Washington has been lost or extensively modified (Buss, 1965). Urban and agricultural development have dried and constricted floodplain habitats.

The valley portion of the Yakima River subbasin still contains remnants of contiguous aquatic and riparian vegetative cover types suitable for wildlife habitat. These riparian habitats are associated with the existing backwaters, sloughs, and oxbows, as well as the sinuous manner of the main river channel.

Riparian and wetland conditions in the Yakima subbasin range from severely degraded to high quality depending on the level of impact by activities such as development, agricultural practices, and grazing. Diking and urban development have constricted floodplains throughout the subbasin and reduced wetland and riparian habitats. Natural stream side-channels and distributaries have been converted to canals and drains. Timing of flow in these channels has been highly altered, causing loss of natural function. Hydrologic alteration has caused loss of native vegetation and replacement by non-native species. The long history of intensive year around livestock grazing resulted in extensive damage to many riparian plant communities throughout the shrubsteppe and valley portions of the subbasin. Riparian habitats are degraded along Toppenish and Satus Creeks because of draining and excessive livestock grazing. Lacking vegetation to slow water run-off and to reduce stream velocity, Roza Creek's stream channel has incised as much as 20 feet in places. Noxious weeds on canal and drain banks and rights-of-way continue to be a problem today for riparian habitat. However, earthen unlined irrigation canal have more value as wildlife habitat than cement-lined canals or piped irrigation delivery systems.

Protecting riparian habitat may yield the greatest gains for fish and wildlife while involving the least amount of area (Knutson and Naef 1997). For example, restoring and protecting floodplain habitats along the Yakima River and associated tributaries benefits many wildlife species as well as fish.

Healthy forested riparian habitat has an abundance of snags and downed logs that are critical to many cavity nesting birds, mammals, reptiles and amphibians. Cottonwood, alder and willow are commonly dominant tree species in riparian areas from the Cascades down through the valley portion of the subbasin. This habitat is often characterized by relatively dense understory and overstory vegetation. Riparian habitats are often forested; however they may contain important sub-components such as marshes and ponds that provide critical habitat for a number of species such as Virginia rails, sora rails, marsh wren (see Wetlands section). Riparian habitats also function as travel corridors between and connectivity to essential habitats (e.g., breeding, feeding, seasonal ranges). Forested riparian habitat in the subbasin has been impacted by cattle grazing, fuelwood cutting conversion to urban development and agricultural uses.

Wetlands

Wetlands provide another unique and significant habitat for wildlife and fish. The importance of wetlands is increased when the adjacent habitats are of high quality and quantity and offer necessary cover for nesting, roosting, and food, such as the riparian gallery forests located along the Yakima River. Wetland habitats along the Yakima River, Toppenish, and Satus Creeks, and the WDFW's Byron Ponds Unit of the Sunnyside Wildlife Area contain some excellent waterfowl nesting and brooding areas. While some quality wetlands habitats remain within the Yakima Subbasin, many have been negatively impacted by agriculture. Conversion of native habitats to irrigated agriculture has resulted in the draining of many more wetlands than it has created in the Yakima subbasin. Irrigated agriculture and general development have altered the hydrologic cycle and associated wetland and riparian habitat. Construction of agricultural drains has dewatered natural floodplain wetlands. Interruption of flood cycles by impoundment along with structural exclusion of river from floodplain has reduced riverine wetland habitats, which were the predominant pre development wetlands in the Yakima Valley. Loss of floodplain inundation has altered habitats by removing ability of native vegetation (e.g. Cottonwoods) to reproduce and survive, and reducing nutrient cycling and productivity of aquatic invertebrates and other plant and animal species that form important components of the food web.

Irrigation related changes in sediment dynamics have affected sediment delivery to wetlands, side channels and main channels in turn affecting the amount and type of submersed macrophyte growth. Many species of wildlife are dependent on healthy native stands of submersed macrophytes. Delivery of irrigation water has created upland wetlands, both in the delivery systems by water leaking through unlined earthen canals, and in tailwater wetlands. These types of wetlands, however, are disappearing through implementation of irrigation water conservation practices and improvements in water delivery systems. Wetlands will be further critically reduced by these water conservation measures.

In addition, the consequences of poor land use in adjacent habitats can negatively impact the quality of the open water by adding numerous chemicals such as pesticides, herbicides, and fertilizers. These can impact wildlife directly through poisoning or indirectly through reduction and/or alteration of the food base.

Many native wildlife species in the Yakima subbasin were dependent on the constant energy sources brought up from the oceans by the fish runs. The loss of these fish runs caused a large loss in energy to the system, altering wildlife population dynamics. Less vegetation, less invertebrates, less wildlife dependent on eating salmon such as bears and eagles. The reduced number of beaver in the subbasin, primarily in the upper, forested portions of the watershed, has also resulted in the drying and loss of many wetland and riparian habitats.

Shrub Steppe

Shrub steppe consists of one or more layers of perennial grass with a conspicuous but discontinuous over-story layer of shrubs. In Washington, these communities usually contain big sagebrush (*Artemisia tridentata*) in association with bunchgrasses, although other associations are found. The National Biological Division of the U.S. Geological Service has identified native shrub and grassland steppe in Washington as an endangered ecosystem (Noss et al. 1995).

Shrub steppe was historically a dominant habitat within the Yakima Subbasin comprising most of the habitat east of the Cascade foothills. Substantial quantities of shrub steppe have been converted to irrigated agriculture, with quantities still remaining Former shrubsteppe habitats, particularly those located in the valley portion of the subbasin contain some of the most intensively managed agricultural land in the nation. Native shrubsteppe plants and animals have been directly replaced by domestic plant and animal species dependent on irrigated agriculture. Conversion has introduced weeds and other non-native plant and animal species that have competed with and replaced natives. Irrigated agricultural land favors different assemblages of species than the native habitats it displaces.

The average cover of big sagebrush was about 10% prior to introduction of livestock into Washington. Currently, most of the remaining shrub steppe habitat in the Yakima Subbasin contains a much higher density of sagebrush, or no sage brush at all. Because livestock do not eat it, sagebrush often increases in density in grazed areas by replacing plants that are targeted by livestock. On the other hand, sagebrush densities are sometimes reduced by range managers to keep the plant from competing with desirable livestock forage plants. Wildfire has also eliminated sagebrush from portions of the Subbasin.

Remaining shrub steppe tends to be fragmented into relatively small patches of habitat that have been degraded in quality (Dobler et al. 1996). The single most significant impact to the sub basin's shrub steppe occurred as a result of the implementation of Yakima Basin Irrigation Projects conversion of native habitat for production of irrigated crops. Some shrub steppe has also been converted for non-irrigated wheat production. Moreover, the pattern of agricultural conversion has resulted in a disproportionate loss of deep soil communities not reflected in typical measures given for habitat loss (Vander Haegen et al. 2000). Other losses have resulted from development, urbanization, and road construction.

The Yakama Nation and US Army's YTC contain two of the largest blocks of relatively high quality shrubsteppe habitat in the Columbia Basin ecoregion. The YTC contains 323,651 acres in Kittitas and Yakima counties, and Yakama Nation approximately 350,000 acres of shrubsteppe habitat in Yakima county.

The Rattlesnake Slope Unit of the WDFW's Sunnyside Wildlife Area contains some high quality remnant stands of the native herbaceous bluebunch wheatgrass community. Wildfires in 1984 and 2000, however, have eliminating the sagebrush component.

Historically, agricultural fields located on both sides of Wenas Creek were used for hay production an/or pasture for the livestock. Similarly, when acquired by WDFW in the late 1960s, hay production was maintained for WDFW's winter elk feeding program. These agricultural fields, however, were seeded to native grasses, forbs, and shrubs in late fall of 1998.

Prior to WDFW ownership the Umtanum Creek Unit of the Wenas Wildlife Area was used for livestock grazing. With the exception of riparian sites, however, grazing impacts were not as pronounced as on other units due to the steep topography that exist on much of the area.

Most of the valley portions of the subbasin around Ellensburg, Yakima, and Toppenish have been converted to irrigated agriculture. Most areas with suitable soils throughout the Rattlesnake Hills north of Sunnyside, Prosser, and Benton City have been converted to both irrigated and non-irrigated agriculture. Because deep soils are associated with productive agriculture lands, deep soils remaining in shrub-steppe habitat in the Yakima subbasin are relatively rare. Shrub steppe with deep soils is required for burrowing or burrow-using wildlife such as badgers, ground squirrels, and burrowing owls. Shrub steppe with deep soils is required for burrowing or burrow-using wildlife such as badgers, ground squirrels, and burrowing owls.

Agricultural

Since the late 1800's, hundreds of thousands of acres of the Yakima Subbasin have been converted to irrigated agriculture habitats. These activities altered the subbasin in profound ways. The converted landscapes did not just represent degraded habitats, but a total removal of native habitats and a replacement with habitats which are entirely different. Areas such as the Kittitas and Lower Yakima Valleys once were extremely large areas of grassland and shrub steppe habitats intermingled with riverine, riparian and wetland associations. The wildlife diversity and habitat complexity associated with these predevelopment habitats was not lost on those responsible for its alteration. One pioneer (Olney, 1916) described the Lower Yakima Valley as follows:

"These valleys were the home of game, ducks, and brant *[geese]* swarmed the lakes, swamps, ponds, sloughs and creeks, prairie chickens *[sharp-tailed grouse]*, sage hens, and rabbits overran the valleys; pheasants *[ruffed grouse]* along the wooded creeks, and the blue-hooter-grouse by the thousands all over the mountains."

Oliver (1983) documents the wildlife use of these new habitats over several decades in the early to mid twentieth century. As more and more lands were converted to agriculture, and as more and more efficient farming practices were utilized, the wildlife abundance and diversity became more and more reduced. Agricultural lands that at one time supported a diverse array of wildlife populations of ring-necked pheasant, California quail, mourning dove and waterfowl, presently support a fraction of their numbers.

The modern agricultural landscape is efficient in terms of crops produced and irrigation water utilized. Idle acreage has been reduced, edge areas are now cropped or mowed, and irrigation canals are lined or maintained vegetation-free. The lower Yakima subbasin has seen a change in crop patterns the last few decades from mostly grain and hay, to permanent crops such as orchards, hops, and vineyards. These permanent crops leave little cover or food for agricultural-associated wildlife species. Pheasants, quail, ducks and doves have become much more scarce in the modern agricultural landscape.

Watershed Assessment

Fish

Watershed Assessment: Yakima River Basin is a comprehensive watershed assessment for this subbasin that was completed in June 2000. It covers the physical setting; surface and ground water resources, uses and rights; water quality and water quality degradation; fish stocks and habitats; data evaluation; and the legal and regulatory considerations. The assessment was conducted under the auspices of the Tri-County Water Resources Agency and its findings are largely consistent with this Yakima Subbasin Summary.

Wildlife

The following watershed analyses have been conducted utilizing the Washington DNR Watershed Analysis method:

Naneum, Washington
Quartz Mountain (Upper Taneum Cr.), Washington
Alps (Upper Cle Elum River), Washington
Cabin Cr., Washington
Keechelus/ Mosquito Cr., Washington
Naches Pass, Washington
West Fork Teanaway, Washington
North Fork Teanaway, Washington
Big Cr., Washington
Ahtanum Cr., Washington - Contains 3 Washington U's
Darland Mt.
Foundation Cr.
Cowiche Cr.

The purpose of these analyses is to provide a structured approach to developing forest practice plans tailored to individual watersheds, based on understanding the biological and physical processes operating in the basin (WDNR and USFS 1996).

The USDA Forest Service (USFS) has conducted the following watershed analyses:

South Fork Manashtash, Washington
Yakima River, Washington
Little Naches, Washington
Naches Mainstem/ Wenas, Washington
Rattlesnake Cr., Washington
Mission Cr., Washington
Bumping River, Washington
American River, Washington
Tieton, Washington
Oak Cr., Washington

The purpose of the watershed analyses was to meet the intent of the "President's Forest Plan" (USDA and USDI 1994), which raised concerns over declining fish resources and the need to protect and improve aquatic and riparian resources (USDA Forest Service – Naches RD, 1995). The results of the analyses were designed to contribute to the USDA Forest Service's planning efforts as well as to contribute to concurrent planning efforts such as PacFish, Columbia River Basin Policy and Implementation Guide (PIG) for Anadromous Fish, Eastside Forest Health Assessment and the Yakima River Subbasin Plan (USDA Forest Service – Naches RD, 1995).

Limiting Factors

Fish

The Yakama Nation is in the process of using existing EDT analyses to refine limiting factors analyses for the Yakima basin. Specifically, for contiguous, environmentally homogenous reaches, the EDT Diagnosis can be used to rank the impacts of specific environmental attributes on productivity and carrying capacity for the most severely impacted life stages in the reaches at issue. This formulation of the diagnosis focuses planners' attention on the specific environmental factors that must be improved, and suggests in addition the targets for effectiveness and validation monitoring.

Table 29 illustrates this kind of EDT-assisted limiting factors analysis, in this case, for upper Yakima spring chinook. The table depicts the mean impact over all reaches of relevant environmental attributes on the most severely impacted life stage, the next most impacted life stage and the third most severely impacted life stage -- parr, wintering parr and fry in this case. Mean impacts by reach and lifestage were computed for each attribute, where 0 represented no impact and 4 a severe impact. It is readily apparent that the most significant environmental impacts (changes from historical conditions) are, in order, **habitat complexity, flow and key habitat**.

The causal interpretation of these data was as follows. There is a pernicious interaction between the loss of habitat complexity and non-normative flows in these reaches. Highways, railroads, residential dikes and agricultural and urban development have virtually disconnected the river from its floodplain and have eliminated, filled or cut off most side channels, sloughs and springbrooks. These reaches are now much narrower, faster and structurally simpler than they were historically, and they contain much less large woody debris (LWD), a legacy of 19th and early 20th century log drives as well as floodplain disconnection. Therefore, most of the slow, shallow, structurally complex off-channel habitat required by chinook juveniles has been eliminated, as has much of the hyporheic habitat that formerly "fertilized" the entire food chain.

Non-normative flows caused by irrigation releases from upper Yakima storage reservoirs then exacerbate the situation. There are three general kinds of impact attributable to non-normative flows. First, channel-maintenance peak flows are much less frequent now, resulting in the gradual silting in and terrestrialization of off-channel habitat. Second, irrigation demand results in flows that are unnaturally high in the summer, and the need to refill reservoirs results in flows that are unnaturally low in winter. High summer flows, combined with a lack of the "velocity cover" formerly supplied by side channels and jog jams, ultimately result in the downstream displacement of juveniles unadapted to such a high energy environment. The scarcity of off-channel habitat and LWD has also resulted in a lack of slow, pool-type habitat, the "key habitat" for all of these life stages. The little structure that remains – perched LWD, riprap and the remaining side channels – is then rendered largely inaccessible when flow drops in the fall and winter as reservoirs are refilled. Finally, there have been unintended consequences of the flip-flop river management scheme. Specifically, salmonid parr are stranded (or isolated and ultimately killed by predators) in remaining side channels when flows are sharply reduced in the fall.

With this explanation in mind, the reason for the order of impacted life stages is apparent. Parr are impacted most severely because almost the entire duration of this life stage occurs during the period of unnaturally high summer flows, and because this life stage alone is impacted by stranding/isolation during flip-flop. Wintering parr are generally impacted more than fry because the fry life stage occurs during the months of March through May, when flows approximate normative values. Fry are therefore largely able to elude the interaction between habitat simplification and flow.

Table x shows a summary table for this kind of EDT-assisted limiting factors analysis – in this case, for upper Yakima spring chinook.

Table 29. Mean impact of environmental attributes on the top three life stages of Yakima spring chinook in the mid- to upper-Yakima alluvial group

Impacts are ranked 0 (no impact) to 4 (severe impact)

	Primary Life Stage	Secondary Life Stage	Tertiary Life Stage
KH	**2.5**	**1.8**	**1.7**
FLOW	**2.8**	**1.5**	**2.3**
HABCOM	**3.0**	**3.2**	**2.5**
TEMP	0.5	0.0	0.0
WITH	0.8	0.3	0.2
COMPO	0.0	0.0	0.2
PRED	0.8	0.0	0.7
CHAN	0.2	1.0	0.3
SED	0.2	0.7	0.0
PATH	0.5	0.0	0.0
CHEM	0.7	0.0	0.0
HARV	0.0	0.0	0.0
OBST	0.0	0.0	0.0

Key: KH = "key habitat", FLOW = "non-normative flow", HABCOM = "habitat complexity", TEMP = "non-normative temperature", WITH = "withdrawals – entrainment or other mortalities associated with irrigation withdrawals", COMPO = "competition with other species", PRED = "predation", CHAN = "channel stability", SED = "fine sediment deposition", PATH = "pathogens and disease", CHEM = "chemicals/toxicants, HARV = "harvest – specifically illegal harvest", OBST = "access obstruction".

Natural and hatchery production of salmon and steelhead in the Yakima Basin is currently in the process of being analyzed by the EDT model. Within the year, a complete analysis will be performed on natural and hatchery production of spring chinook, fall chinook, coho and summer steelhead. An initial diagnosis of the factors constraining performance of spring chinook has already been completed, as well as a preliminary analysis of the relative effectiveness of enhancement strategies based on the diagnosis. Progress on the EDT analysis of Yakima steelhead has been slowed by the need to develop special procedures to account for the interactions between anadromous and resident ecotypes of *O. mykiss*. More specifically, because some populations of rainbow trout and summer steelhead in the Yakima Basin genetically indistinguishable and presumably not reproductively isolated (Busack 1997), it has been necessary to specify the conditions which favor one ecotype or the other, and to incorporate these conditions in the EDT model. Significant progress on this problem has recently been made, and it is anticipated that one or two months will be needed to bring the steelhead analysis to the same point as spring chinook. Fall chinook and coho will be analyzed after spring chinook and steelhead.

EDT analyses can be used to prioritize among reaches in terms of both their current “preservation value” and their possible “restoration potential.” Moreover, because of a considerable similarity in the habitat requirements and life history among spring chinook, fall chinook and to a lesser extent, coho, the results of the spring chinook analysis can with due caution be generalized to “all Yakima Basin salmon.”

The term “restoration potential” denotes the improvement in performance of a salmon or steelhead population if the environmental conditions in a specific reach were to be fully restored to pristine, normative conditions. In EDT analysis, all aspects of the performance of a salmon population are reduced to productivity (especially adult recruitment rate), equilibrium abundance and life history diversity (the proportion of the biologically possible life history types which are viable – which have a productivity of 1.0 or more). “Preservation value” refers to the degree to which current performance is dependent upon one or more specific reaches. The two concepts may seem related but are in many cases actually quite different. This is evident when one considers the rather common case of a severely degraded reach that historically was a major producer.

Two final points about the process of EDT analysis must be made to provide proper context for the results to be presented. In calculating both restoration potential and preservation value, the EDT model performs a “splice analysis”. In this process, new values for a single reach are “spliced” into the data matrix for all reaches in the basin, and new, basin-wide values are computed to illustrate the impact of the splice on global performance. In the restoration potential splice, environmental parameters estimated for historical conditions are spliced into each reach. In the preservation value splice, “anti-PFC” values for environmental conditions are used. “Properly Functioning Condition” (PFC) is a concept developed by NMFS. Collectively, these properly functioning environmental conditions ensure that all aspects of the environment retain a sufficient degree of normative character to ensure the perpetuation of the population. “Anti-PFC” conditions have also been described, and represent the suite of conditions under which viability is threatened. As mentioned, the EDT analysis uses anti-PFC conditions in the preservation value splice. The difference in Basin-wide performance between current conditions and the anti-PFC splice may be thought of as an approximation to Basin-wide performance if the reach in question were somehow removed.

The impact of a splice analysis is expressed as a proportional change from performance under current conditions. That is to say, if P is Basin-wide performance under current conditions, and P' is performance after a splice, the impact is expressed as (P – P')/P. In all but a handful of unusual situations, (P – P')/P with be a positive proportion for a restoration potential splice. Similarly, in all but a few aberrant situations, (P – P')/P will be a negative proportion for a preservation value splice. For readability, however, the impact of preservation value splices is expressed as a positive proportion, indicating the degree to which current performance is dependent upon the reach in question.

Preservation Value

Table 30 and Figure 66 summarize the top 25 reaches (of the 142 modeled) in terms of preservation value for Yakima spring chinook. More particularly, these 25 reaches provide approximately 90% of the total mean preservation value for spring chinook in the Yakima Basin. "Mean preservation value" refers simply to the mean of the individual preservation values for productivity, equilibrium abundance and life history diversity. Therefore, given the current spawning distribution and observed patterns of redistribution over the freshwater life history, these 25 reaches support all but a negligible proportion of spring chinook production at the present time.

Table 30. Contribution of critical reaches to Preservation Value for Yakima spring chinook.

REACH	CONTRIBUTION TO CURRENT PERFORMANCE				
	PROD	ABUND	LH DIV	MEAN	CUM
Yakima, Manastash - Taneum	3.89%	14.83%	8.82%	9.18%	8.19%
Yakima, Marion Dr - S'side Dam	0.00%	18.38%	8.82%	9.07%	16.28%
American R.	6.71%	10.35%	8.82%	8.63%	23.97%
Yakima, Ahtanum - Naches	0.00%	16.80%	8.82%	8.54%	31.59%
Yakima, Wilson - Manastash	2.47%	10.09%	5.88%	6.15%	37.07%
Yakima, Teanaway - Cle Elum	3.18%	8.87%	5.88%	5.98%	42.41%
Yakima, Roza Dam - Umtanum	0.00%	9.29%	5.88%	5.06%	46.92%
Naches, Cowiche - Wapatox	0.00%	8.90%	5.88%	4.93%	51.31%
Yakima, Cle Elum – Little	2.47%	6.39%	5.88%	4.92%	55.70%
Yakima, Swauk - Teanaway	1.77%	6.37%	5.88%	4.67%	59.86%
Naches, Nile - L. Naches	1.06%	5.42%	5.88%	4.12%	63.54%
Yakima, Umtanum - Wilson	0.00%	5.53%	5.88%	3.80%	66.93%
Yakima, Big Cr. – Easton Dam	2.12%	4.51%	2.94%	3.19%	69.78%
Naches, Tieton - R'snake	0.00%	5.45%	2.94%	2.80%	72.28%
Yakima, Taneum – Swauk	1.06%	4.20%	2.94%	2.73%	74.71%
Yakima, Wenas - Roza Dam	0.00%	4.95%	2.94%	2.63%	77.06%
Yakima, Cabin Cr - Keechelus Dam	0.00%	3.33%	2.94%	2.09%	78.92%
Yakima, Naches – Wenas	0.00%	5.74%	0.00%	1.91%	80.63%
Yakima, Satus - Toppenish	0.00%	5.64%	0.00%	1.88%	82.31%
Cle Elum, mouth to Dam	0.00%	2.36%	2.94%	1.77%	83.88%
Logy Cr.	0.00%	1.82%	2.94%	1.59%	85.30%
Yakima, Mabton – Satus	0.00%	4.45%	0.00%	1.48%	86.62%
Yakima, S'side Dam - Wapato Dam	0.00%	4.38%	0.00%	1.46%	87.92%
Satus, Mule Dry – Dry	0.00%	4.06%	0.00%	1.35%	89.13%
Bumping, American - Dam	0.00%	0.76%	2.94%	1.23%	90.23%

“PROD,” “ABUND” and “LH DIV” represent an index of the proportion of current productivity, equilibrium abundance and life history diversity attributable to a given reach. “MEAN” is the average of the productivity parameters, and “CUM” represents the cumulative mean contribution.

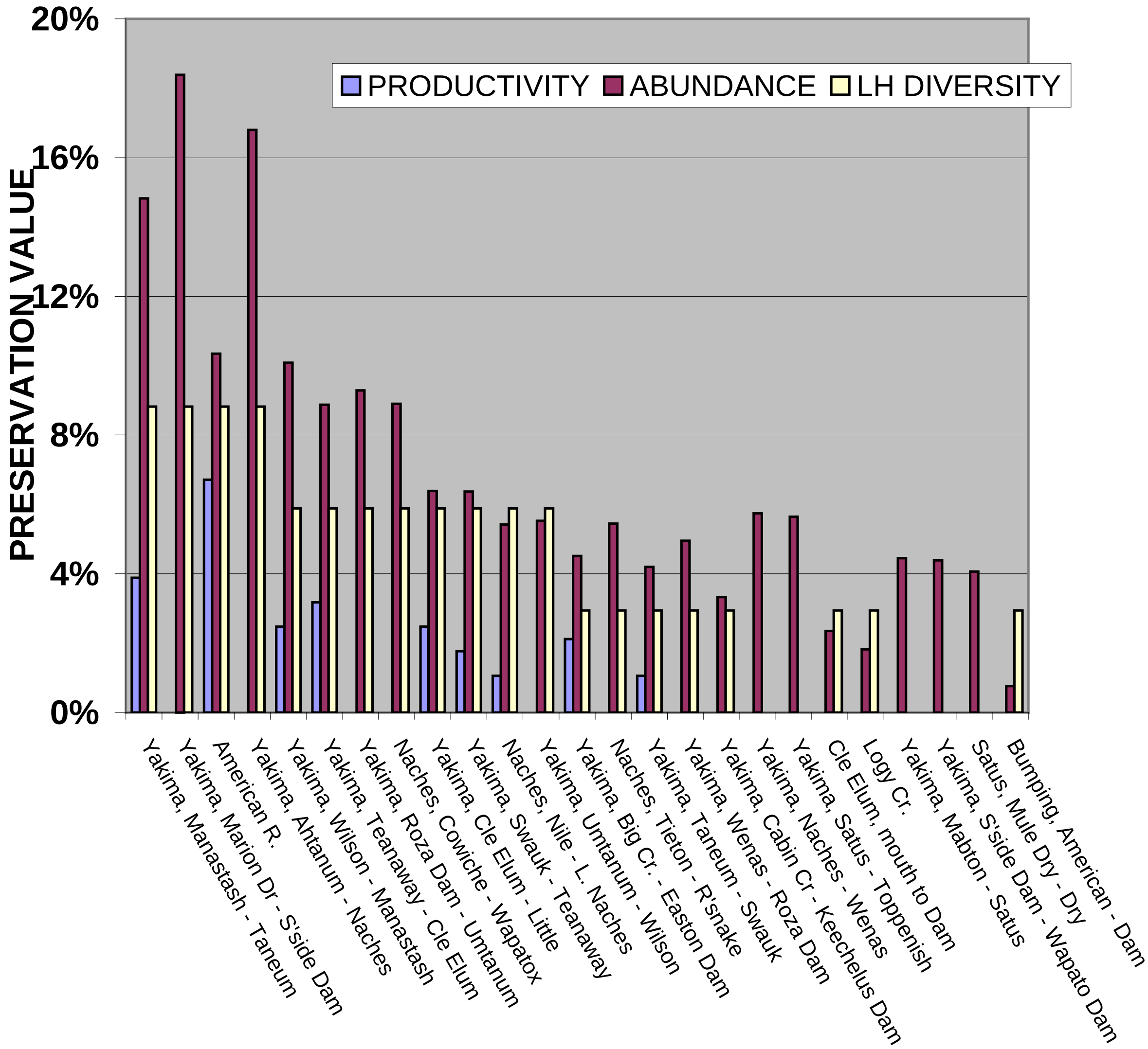


Figure 66. The 25 Yakima basin reaches responsible for 90% of basin-wide mean preservation value for spring chinook

To those familiar with habitat conditions in the Yakima basin, the presence of most of these reaches is not surprising. Thirteen of the reaches (red font in Table 30) are the major anastomosing (connecting), alluvial reaches currently accessible to spring chinook, and would be expected to play a major role in supporting current production. Five reaches (in blue) represent the major confined, canyon areas in the basin. It is expected that they also should be important in light of the fact they provide habitat to parr for a great portion of the year, as well as holding habitat for pre-spawners, even though very little or no spawning occurs in them.

Three reaches, in black, represent tributaries, two of which are somewhat surprising: Logy Cr. (a Satus Cr. tributary) and Satus Cr. From Mule Dry to Dry Cr. These reaches were included because the current EDT analysis indicates conditions in portions of Satus Cr. and in Logy Cr. are consistent with the support of a viable if small population of spring chinook. These reaches have been retained in the list of high-value preservation reaches even though spring chinook production does not currently occur in the Satus watershed. Conditions do indeed appear to be good enough to support spring chinook. Also, historical data (Bryant and Parkhurst, 1950) indicate that spring chinook were present in Satus Cr. before 1910. Possibly, Satus Cr. no longer supports spring chinook because they were extirpated many years ago (primarily because of impassible diversions which have since been eliminated), and the current populations of spring chinook home to areas so far upstream as to be very unlikely to stray into Satus Cr.

Finally, four of the reaches in Table 30 (in green) represent portions of the lower Yakima mainstem. Their inclusion is at first surprising in light of the fact lower Yakima habitat has been so thoroughly degraded in so many ways. The explanation, however, is that the lower mainstem still affords good to excellent habitat for overwintering, and there is abundant evidence (Fast et all 1991) that current spring chinook juveniles migrate considerable distances from the upper basin to take advantage of this habitat.

Figure 66 indicates that there is a fairly regular, if steep, gradient across reaches in terms of current preservation value. When, however, the various elements of composite preservation value (abundance, productivity and life history diversity) are examined separately, anomalies appear. Specifically, life history diversity and productivity are distributed unevenly across reaches. The explanation for life history diversity is relatively simple. Life history diversity increases as the proportion of sustainable life history patterns increase, regardless of the abundance of the individual patterns. Moreover, so long as the expected productivity is greater than 1.0, not even the degree of productivity is important. Therefore, relatively small and/or unproductive reaches – like the lower Cle Elum River or the Bumping River from Bumping Dam to the American – are disproportionately important to diversity simply because they generate a higher proportion of sustainable life history patterns.

The uneven distribution of *productivity* across reaches may represent something more significant. When the EDT data for preservation value are examined closely, it is found that only 12 reaches in the entire basin contribute meaningfully to basin-wide productivity. These reaches are graphically depicted in Figure 67. With some exaggeration, these data imply that all other reaches either have no effect on productivity or in fact represent a productivity sink. A rather strong caveat, however, must be laid against this assertion. Productivity preservation value, as currently estimated, is relative to “anti-PFC” habitat conditions in the spliced reach. To the degree that the current values for anti-PFC environmental conditions are actually higher than they should be, and would in fact support minimally viable populations, the case is overstated (*viz.*, more than the identified 12 reaches would substantially contribute to basin-wide productivity).

The reaches identified in Figure 67 do, however, make sense. They include most of the highest quality reaches in the basin and, with two exceptions, *all* of the reaches in which spawning occurs. It is relatively easy to understand why only spawning reaches should elevate net basin-wide productivity: unless a reach supports spawning, no matter its quality for the other life stages, it represents only a site of mortality (no net increase in numbers). Two reaches in which limited spawning occurs now do not appear in Figure 67: the mainstem Yakima from Easton Dam to Cabin Cr. and from Cabin Cr. to Keechelus Dam.

These reaches fail to make a significant contribution for two reasons: access has been limited at Easton Dam, and very large releases from Keechelus reservoir during the incubation period cause bed scouring and a substantial depression of egg-to-fry survival.

One final point in the context of preservation value should be made regarding the contribution of reaches and areas outside the Yakima Basin. The EDT model does analyze the impacts of habitat conditions in the Columbia River and the ocean. The preceding analysis omitted such non-local impacts. This omission, however, does little to distort the picture, as 16th is the highest preservation value rank for a non-local reach. Indeed, when limiting consideration only to those reaches comprising 90% of total preservation value, only two out-of-basin reaches appear: the Columbia from John Day Dam to McNary Dam (16th of 27) and the Columbia from the Cowlitz confluence to Bonneville Dam (18th of 27).

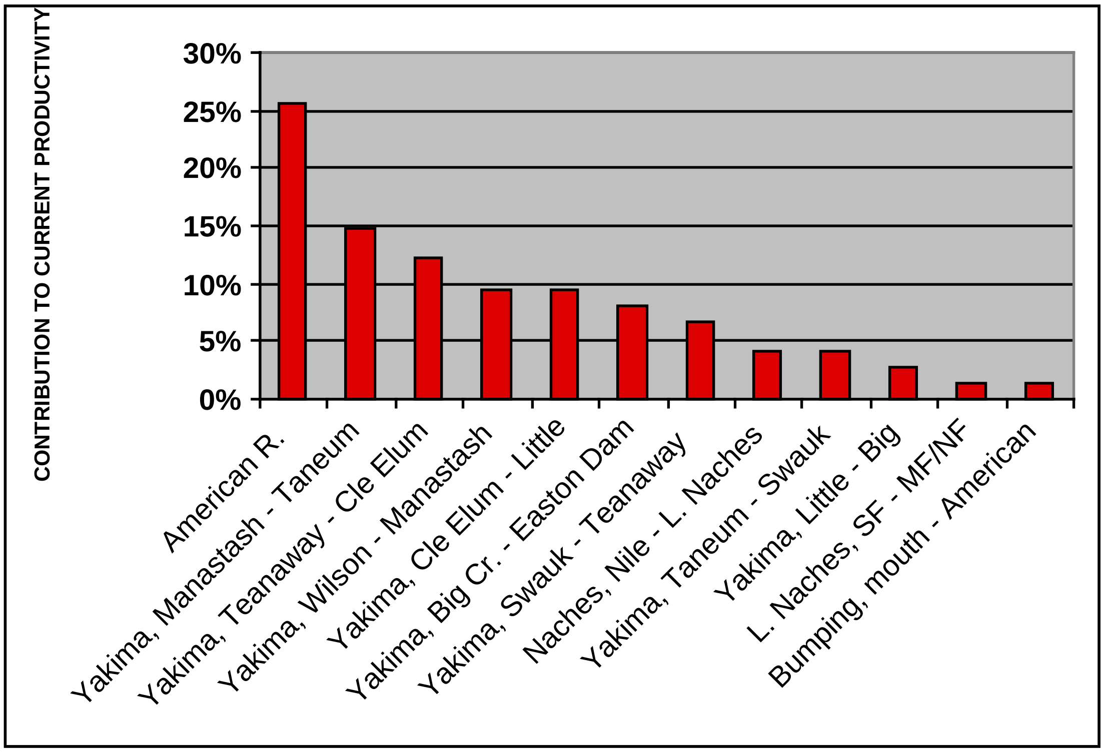


Figure 67. The 12 reaches in the Yakima Basin for which productivity preservation value is greater than zero.

Restoration Potential

Restoration potential perhaps bears a closer resemblance to the common notion of "limiting factors" than does preservation value. It entails a comparison of habitat and biological performance under contemporary and normative, historical conditions, and therefore identifies both the life stages most severely impacted and the environmental attributes responsible for the impact. This level of analysis might be characterized as a "proximate diagnosis".

The proximate diagnosis also leads directly to a provisional prioritization of reaches for enhancement work. This prioritization is merely provisional, because it is based on the *full restoration* of each spliced reach. Obviously, full restoration will rarely if ever be possible in this day and age. Therefore, the initial prioritization must be substantially reshuffled to reflect the degree to which restoration of normative conditions is feasible in individual reaches.

To be truly useful, however, even such a qualified restoration potential analysis must identify the ultimate causes of changes in habitat condition and population performance. For example, it is not enough to know that the reaches with greatest restoration potential all have been degraded primarily at the incubating egg life stage, and this as the proximate result of high levels of fine sediment loading. In order to design effective enhancement actions, it must be determined whether this sediment problem is attributable to mass failure associated with logging roads, or bank instability associated with riparian degradation and overgrazing, or point discharges from irrigation returns, and so on. The remedy for an incubation problem would clearly be quite different under each of these scenarios.

EDT analysis does not address ultimate causation. More precisely, it does not explicitly link specific management actions to environmental impacts (although it may do so in the future). This linkage, both in regard to diagnosis and the design of remedial measures, must occur outside EDT. EDT-based efforts in the Yakima Basin, at least for spring chinook, have reached the end of the proximate stage. Further progress requires the formation of an inter-disciplinary group of scientists and resource managers to complete the ultimate-cause diagnosis, and to design appropriate restoration actions.

Table 31 lists the 35 reaches inside the Yakima Basin that represent 90% of the restoration potential for Yakima spring chinook. The list includes 13 mid- to upper-Yakima alluvial reaches, nine upper Yakima tributaries, seven dams, four mainstem Naches reaches, and two Naches tributaries. The relative contribution of these reaches to restoration potential is as follows:

- Mid- to Upper Yakima alluvial reaches (below and including the lower Cle Elum R.; red): 52.1%
- Yakima and Naches tributaries (orange): 12.5%
- Dams (blue): 9.2%
- Lower Naches mainstem (below the Tieton confluence; dark green): 7.7%
- Upper Yakima (above the Cle Elum confluence; light green): 3.7%
- Lower Yakima (below the Ahtanum confluence; black): 3.4%
- Upper Naches mainstem (above the Tieton confluence): 1.7%.

Table 31. The 35 reaches within the Yakima Basin that represent 90% of the cumulative restoration potential for Yakima spring chinook (reaches outside the Yakima omitted)

Reach	RESTORATION POTENTIAL BY PERFORMANCE PARAMETER			MEAN POTENTIAL	CUMULATIVE POTENTIAL
	ABUNDANCE	PRODUCTIVITY	LH DIVERSITY		
Yakima, Manastash - Taneum	122.7%	94.5%	3.1%	73.5%	13.3%
Yakima, Ahtanum - Naches	109.1%	103.1%	3.1%	71.8%	26.4%
Yakima, Teanaway - Cle Elum	67.0%	69.5%	0.0%	45.5%	34.6%
Yakima, Wilson - Manastash	65.7%	70.5%	0.0%	45.4%	42.9%
Yakima, Naches - Wenas	55.7%	67.8%	3.1%	42.2%	50.6%
Naches, Cowiche - Wapatox	40.0%	51.0%	3.1%	31.4%	56.3%
Teanaway, mouth to NF	36.8%	29.5%	9.4%	25.2%	60.8%
Yakima, Cle Elum - Little	17.4%	22.9%	0.0%	13.5%	63.3%
Prosser Dam	17.1%	9.6%	6.3%	11.0%	65.3%
Satus, Mule Dry - Dry	12.4%	13.0%	6.3%	10.5%	67.2%
Taneum Cr., mouth to forks	10.4%	8.6%	6.3%	8.4%	68.7%
Cle Elum, mouth to Dam	10.9%	14.0%	0.0%	8.3%	70.2%
Sunnyside Dam	12.8%	2.4%	9.4%	8.2%	71.7%
Cle Elum Dam	7.0%	0.0%	15.6%	7.5%	73.1%
Wapato Dam	10.8%	3.8%	6.3%	6.9%	74.3%
Wenas Cr., mouth to NF	8.6%	2.7%	9.4%	6.9%	75.6%
Yakima, Big Cr. - Easton Dam	8.1%	12.0%	0.0%	6.7%	76.8%
Naches, mouth - Cowiche	8.9%	10.3%	0.0%	6.4%	78.0%
Tieton Dam	6.2%	2.7%	9.4%	6.1%	79.1%
Yakima, Marion Dr - Sunnyside Dam	13.6%	0.0%	3.1%	5.6%	80.1%
Yakima, Delta - Horn Dam	8.6%	4.1%	3.1%	5.3%	81.0%
Naches, Tieton - R'snake	6.1%	6.2%	3.1%	5.1%	82.0%
Tieton, mouth - Dam	5.6%	1.4%	6.3%	4.4%	82.8%
Naches, Nile - L. Naches	5.9%	7.2%	0.0%	4.4%	83.6%
Wapatox Dam	4.9%	4.8%	3.1%	4.3%	84.4%
Roza Dam	4.7%	3.8%	3.1%	3.9%	85.1%
Manastash, mouth to forks	3.9%	2.7%	3.1%	3.3%	85.6%
Satus, Dry – Logy	4.3%	2.4%	3.1%	3.3%	86.2%
Big Cr.	2.1%	1.0%	6.3%	3.1%	86.8%
Yakima, Horn Dam - Benton Br.	3.8%	1.7%	3.1%	2.9%	87.3%
SF Manastash Cr.	1.9%	0.3%	6.3%	2.8%	87.8%
Horn Dam	3.3%	2.1%	3.1%	2.8%	88.4%
Cowiche, mouth - SF	2.1%	2.7%	3.1%	2.7%	88.8%
Yakima, Mabton - Satus	4.2%	0.7%	3.1%	2.7%	89.3%
Ahtanum, mouth to WIP Dam	8.0%	0.0%	0.0%	2.7%	89.8%
Yakima, Satus - Toppenish	4.1%	0.3%	3.1%	2.5%	90.3%

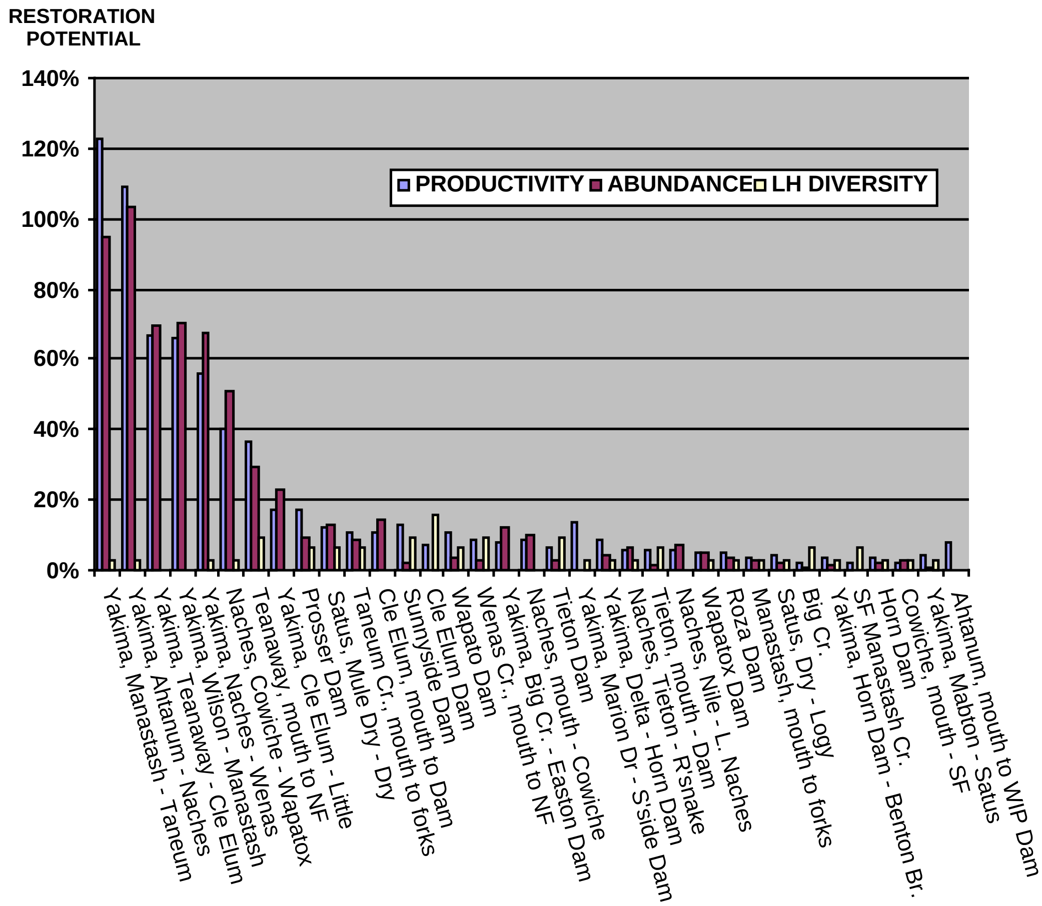


Figure 68. The relative contributions of the 35 Yakima Basin reaches providing 90% of estimated mean restoration potential.

Figure 68 graphically depicts what is less evident in Table ? that contribution to restoration potential within the Yakima Basin is very unequally distributed across reaches. Fully 60% of basin-wide restoration potential is located in just the top eight reaches, which represent all but one of the major alluvial, anastomosing reaches in the basin. This is expected, given the importance of such reaches to productivity, carrying capacity and biodiversity and the very great level of degradation that has occurred in them over the last 150 years. The one major exception to this rule is the huge and hugely complex reach extending roughly from the confluence of Ahtanum Cr to Toppenish Cr. This reach does not play the same role for spring chinook that the other alluvial reaches do because it is a lower gradient, lower river reach, and is simply qualitatively different: it was the major spawning area for summer and fall chinook, but not spring chinook. Perhaps the main reason for this is that, even historically, water temperatures would have been excessive for spring chinook during their September spawning period, but not for summer and fall chinook which spawn one to three months later.

Functional Analysis of Factors Limiting Natural Production

In functional terms, the factors that limit the current productivity and carrying capacity of the component reaches of the subbasin may be divided into 10 different classes. Factors affecting current natural production have been classified in terms of the specific element of the aquatic ecosystem they impact most directly. Aquatic ecosystems can be disaggregated into abiotic and biotic components. Six distinct parameters fully describe the abiotic components, and four describe the biotic components. Abiotic elements include the following parameters:

1. Water quality: temperature, suspended sediment, turbidity, chemical pollution/pesticides, nutrient concentration, dissolved oxygen, biological oxygen demand.
2. Habitat accessibility: presence of physical barriers to anadromous salmonids.
3. Habitat structure: pool frequency and quality, fine sediment delivery and deposition, size distribution of substrate, and the quantity and distribution of large woody debris (large woody debris), off-channel habitat (e.g., side channels and sloughs) and refugia (near-pristine habitat patches sheltering "core populations").
4. Channel condition and dynamics: width-to-depth ratio, streambank stability, channel stability, channel confinement and simplification, floodplain connectivity.
5. Instream flow/hydrology: similarity of peak and base flows to normative values, similarity of drainage network to the historical drainage network, mortalities (entrainment, predation, stranding) caused by irrigation or hydropower diversions.
6. Watershed condition: road density, condition and location, disturbance history and the quantity and distribution of riparian reserves (habitat patches of natural, late succession riparian vegetation providing normative rates of large woody debris recruitment, shading, etc.)

The four major biotic elements are:

1. Predation, both inter- and intra-specific.
2. Competition, both inter- and intra-specific (hatchery-wild and between resident and anadromous morphs of the same species, especially *O. mykiss*).
3. Pathogens/Parasites
4. Mutualism, species that benefit each other, as in the fertilization of infertile streams to the benefit of the entire aquatic community by salmon carcasses, or water retention and the beneficial habitat structure provided by beaver dams. A major mutualistic element, riparian vegetation, has for organization sake been grouped with habitat structure, an abiotic parameter.

Classified in terms of these ten parameters, the major factors currently limiting natural production of salmon and steelhead are as follows:

Water Quality

Excessive water temperatures in mainstem Yakima River

Maximum water temperatures in the lower hundred miles of the Yakima mainstem that reaches or exceeds lethal levels for salmonids. This thermal change occurred primarily as a result of storing much of the cold spring runoff in reservoirs and preventing the recharge of hyporheic and shallow floodplain aquifers by eliminating regular spring floods in alluvial reaches. A contributing factor is the loss of riparian vegetation that moderated thermal heating of the stream and adjacent soils and shallow aquifers.

Excessive water temperatures in tributaries

Summer temperatures are frequently excessive in the lower reaches of Satus, Toppenish and Ahtanum Creeks, as well as the Teanaway River. This problem is caused by removal of riparian vegetation and consequent loss of shading, and low flows resulting from irrigation withdrawals (Toppenish, Ahtanum and the Teanaway) or degradation of wet meadows at the headwaters (Satus Cr.).

Excessive deposition of fine sediment

In the Yakima mainstem. The amount of fine sediments deposited in the middle and lower Yakima, from Wilson Creek (RM 146) to the Columbia confluence, has severely degraded many miles of spawning habitat and partially or completely filled pools essential to juvenile rearing and adult holding. This problem is clearly caused by extraordinarily silt-laden irrigation returns (e.g., Sulphur Cr, Granger Drain) and natural creeks that receive massive silt loads from irrigation returns and direct agricultural runoff (e.g., Wilson Cr, Ahtanum Cr).

In major tributaries. Excessive sediment loading poses similar problems in a number of important tributaries, including Satus Cr and all of its tributaries, Toppenish Cr and its tributaries, the lower Naches River, the Little Naches River, Ahtanum and Cowiche Cr, and the Teanaway River. In these tributaries, increased sediment loading is caused excessive by road density in the watershed, roads located immediately adjacent to streams, poorly maintained roads and/or bank destabilization associated with overgrazing.

Sediment associated with operation of irrigation diversion dams. Post-irrigation-season maintenance of gates and/or bypass screens at a number of dams has resulted in the discharge of large quantities of silt and fine sediments that impact downstream spawning areas. At Roza Dam, these incidents result from the lowering of Roza pool to gain access to rotary drum screens for maintenance. When the pool is lowered, much of the sediment deposited during the previous year is resuspended and deposited on spring chinook, steelhead and coho spawning areas downstream[19]. At the Easton diversion (RM 202.5), periodic maintenance on the dam gate also requires the lowering of the impoundment (Lake Easton). Exposure of lake bottom sediment has an effect similar to that at Roza, especially when fall rains erode soft basin walls and resuspend mud, which is carried into the most important spring chinook spawning area in the basin.

Habitat Access

Blocked by major impoundments

Keechelus, Kachess, Bumping and especially Rimrock and Cle Elum Dams are unladdered and have no facilities to assist outmigrating smolts. Consequently, they have blocked access to hundreds of miles of good to excellent habitat.

Blocked by small diversions

Many dozens of smaller dams and diversions on tributaries restrict access to an area amount of spawning and rearing habitat that collectively rivals the losses attributable to the major impoundments. Historically productive tributaries that have been partially or totally blocked by irrigation diversion include the Yakima mainstem between Easton and Keechelus Dams, Big Cr, Little Cr., the Teanaway River mainstem and all three of its forks, Taneum Cr., Manastash Cr., Reecer Cr., Wilson Cr. and its many tributaries, Wenas Cr, Cowiche Cr., Ahtanum Cr., upper Toppenish Cr. (above the Toppenish Lateral Canal),

[19] The Bureau of Reclamation has recently attempted to minimize this problem by conducting their maintenance with the pool only partially drawn down.

Simcoe Cr., and the North Fork of Simcoe Cr. Often problem diversions on these tributaries block adult access because they lack fishways and are too high to be jumped. However, nearly as frequently these diversions block access by partially or totally dewatering the downstream reach at critical times of year. Most of the problem diversions in these tributaries are either poorly screened or lack screens entirely. Details on these diversions may be found in the Yakima Subbasin Plan (Anon 1990).

Habitat Structure

Elimination of off-channel habitat

Side channels, sloughs and off-channel "alcoves" have been filled or disconnected from the mainstem river as a result of streamside farming, residential development and the construction of railroads and roads. These activities have drastically reduced the area of structurally complex, multi-channel rearing habitat for juveniles.

Inadequate Large Woody Debris

With the exception of some isolated headwater streams that have been protected or have fortuitously escaped development, the entire drainage suffers from a severe lack of large woody debris (large woody debris). Combined with unnaturally high flows during the late spring and early summer, the scarcity of large woody debris has severely reduced the quantity and quality of rearing habitat for salmonid fry, and especially for late-emerging steelhead fry. The scarcity of large woody debris can be attributed to reduced recruitment, which in turn is caused by the removal of riparian trees associated with diking, road maintenance and construction, riparian logging and overgrazing, and residential development in the floodplain (particularly in Kittitas County).

Channel Condition and Dynamics

Impacts of dikes, levees and road embankments

Channel structure has been substantially modified in the Yakima River Basin by the construction and maintenance of dikes, levees and roads. Areas with particularly severe impacts of this kind include the mainstem Yakima in the vicinity of the cities of Ellensburg and Yakima, virtually the entirety of Satus Cr and the Naches and Little Naches Rivers, and the critical upper Yakima spring chinook spawning and rearing area extending from Easton Dam to the Teanaway River confluence. By narrowing and straightening the channel, dikes and road embankments increase stream velocities substantially, thereby displacing fry and, over time, removing spawning gravel. Floodplain roads have played the dominant role in simplifying tributary channels. Road embankments confine the channel like a dike, but also prevent establishment of riparian vegetation and increase the delivery of fine sediment. Reaches in which channel structure has been degraded by road embankments can be found throughout the Yakima River drainage.

Impacts of logging, grazing and mining

Although dikes, levees and roads have had the largest impact on channel condition and function, logging, mining and grazing have played locally dominant roles, causing increased bank erosion and fine sediment delivery, channel disturbance, and loss of riparian function. Logging impacts have been significant in the Little Naches drainage and a number of upper Yakima tributaries (e.g., Cabin Cr and Big Cr). Historical and ongoing mining activities have severely disrupted channel structure and function in Swauk Cr. The impact of historical overgrazing has been severe in Satus Cr, and especially its Dry Cr tributary.

Instream flow/Hydrology

Global impact

The hydrograph has bee significantly distorted by using storage reservoirs to regulate instream flows for irrigation throughout most of the basin. Along the entire length of the mainstem Yakima, the hydrograph has been "inverted and truncated", with highest sustained flows occurring in the summer, unnaturally low flows occurring during the winter, and diminished peak flows year-round. Along the Tieton/Naches corridor, the hydrograph is deformed by a river management scheme known as "flip-flop" (see below). This scheme diminishes the normative, late spring peak flow period, exacerbates the late summer low-flow period, dramatically increases flows during late summer and early fall (early September through mid-October) and unnaturally decreases flows during the winter and early spring. The impact of these changes has been most severe on fry and early parr, although a very significant secondary effect has been the degradation of spawning substrate in the Tieton and lower Naches. Water velocity during later spring and early summer is excessive in the 110 miles of the mainstem Yakima River from Keechelus Dam to Sunnyside Dam. Combined with the severe structural simplification that has also occurred in this area, the loss of rearing habitat has been enormous.

Site- and structure-specific impacts

The global effect of a non-normative hydrograph is cumulatively more important than isolated impacts and those associated with specific structures. Nevertheless, some site- and structure-specific impacts are important enough to mention. These are:

Side channel fry stranding. Fry are regularly stranded in the late spring and early summer in side channels of the Yakima River in the vicinity of the towns of Ellensburg, Cle Elum and Easton, and in the Cle Elum River near Cle Elum Dam[20] due to irrigation-related downramping. A similar impact occurs in the fall in association with the end of irrigation season and the beginning of the period of reservoir re-filling.

Parr displacement. Parr are probably displaced from suitable rearing/overwintering areas in upper Yakima to unsuitable areas downstream by sustained, unnaturally high flows in the late spring and summer.

Naches impacts associated with "flip flop". Under the reservoir and river management scheme called "flip-flop" releases from upper Yakima reservoirs are substantially reduced in early September at the same time as releases from Rimrock and Bumping reservoirs are increased. By this expedient, irrigation water is provided to major mid-Yakima irrigation systems and upper Yakima spring chinook are forced to spawn lower in the river channel, reducing the likelihood of redd desiccation when flows are further reduced in the late fall during reservoir refilling. Unfortunately, this management scheme has also greatly reduced quality and quantity of spawning substrate and rearing habitat in the lower Naches and Tieton Rivers. Releases from Rimrock and Bumping are minimized from early spring through early September, resulting in unnaturally low flows which dry up all or most of the side channels in the lower Naches, radically reducing the quantity of fry/parr rearing habitat and probably displacing fish downstream into the middle and lower Yakima. Water temperatures and predator densities in this portion of the Yakima are such that the survival of displaced juveniles is unlikely. Just when flows reach their regulated minimum -- early September -- Flip-flop occurs, and discharge in the lower Naches increases by an

[20] The Bureau of Reclamation has, however, recently attempted to minimize the impact in the Cle Elum by holding flows at levels sufficient to prevent side channel de-watering whenever storage is sufficient to meet anticipated irrigation demand.

order of magnitude. Again, downstream displacement of juvenile salmonids probably occurs as a result of this dramatic and relatively sudden change in flow[21]. Because the period of high flow is six or seven weeks, much of the small gravel required for spawning has been flushed out of the Tieton and lower Naches.

"Water holes". The production of "holes in the river", or "water holes" below a number of irrigation diversion frequently occurs during low-flow years. At such times, some irrigation diversions regularly produce episodes of near-dewatering in the downstream reach, reminiscent of the complete dewatering episodes of the 1930's and 40's. These diversions include Wapatox Dam, Sunnyside Dam and Prosser Dam, and occasionally Easton Dam. Water holes are generally produced by an inability to forecast increased irrigation demand and to increase releases from upstream storage reservoirs fast enough. They can be particularly devastating when they occur during fry emergence (Easton and Wapatox) or during the smolt outmigration season (all sites but especially Sunnyside and Prosser).

Elimination of an annual flood. The elimination of regular spring floods in (historically) unconfined alluvial reaches by a combination of reservoir flood control and extensive diking downstream has had a number of negative effects. The most significant of these is a major reduction in the quantity of cool, hyporheic and floodplain ground water to sustain summer base flows. This reduction in groundwater inflow is one of the major causes of the increased water temperature in the lower Yakima. Other adverse impacts include a reduction in the abundance of prey organisms for juvenile salmonids, accelerated channel incision in aided areas and the dewatering of off-channel habitat, structural simplification of main channel habitat, increased destructiveness of winter floods on deposited eggs, and the loss of inundated floodways which historically provided abundant, structurally complex fry rearing areas.

Bypass system mortalities. Predatory fish and birds congregate around a number of smolt bypass systems at a number of diversion dams, but especially Horn Rapids, Prosser, Sunnyside and Wapato Dams. Smolt losses to these predators can be high when flows are low and water temperatures high.

Logging-related. Peak flows have been substantially elevated in some headwater streams due to roads and logging (e.g. Cabin Creek, Big Creek, the Teanaway River). Roads capture runoff and efficiently transport it to the stream, precluding ground infiltration. Large scale removal of trees and vegetation also allows more rapid melting of the snow pack and release of winter and spring runoff.

Adult and juvenile mortalities associated with the Columbia River hydropower system.

Watershed Condition

Watershed conditions have been degraded in the Yakima River basin from a wide array of land management activities. Logging, mining, grazing, roads and clusters of residential and recreational development have negatively affected headwater areas and tributaries in the watershed. Roads, dikes, residential development, agriculture practices, grazing, manipulation of flows, and gravel mining have affected the middle watershed. Agriculture practices, dikes, irrigation return flows, residential development and manipulation or lack of flows mostly affects lower portions of the watershed.

[21] The Bureau of Reclamation has also attempted to reduce the impact associated with flip-flop by extending the duration of the flow change from 3-5 days to 10 days or more.

Predation

Current losses of juvenile salmon and steelhead to predators are thought to constrain natural production significantly. These losses may be due to a combination of factors including:

A. The introduction of exotic piscivorous fish, especially smallmouth bass, into the lower Yakima.
B. The transformation of much of the lower mainstem into warm, slow-moving reaches that accelerate feeding rates of all piscivorous fish and affords good rearing habitat for pikeminnow populations.
C. Increased exposure time to predator populations associated with reduced instream flows.
D. The construction of five major and hundreds of smaller irrigation diversions and smolt bypass systems which have eliminated wholesale entrainment mortalities but have also created excellent foraging sites for piscivorous fish and birds.
E. The radical simplification of rearing habitat, which has increased the vulnerability of parr and smolts to predatory birds, especially mergansers in the upper basin.
F. A recent observation in the area of predation suggests that a migrating smolt, whether hatchery-reared or wild, will have a higher probability of surviving passage through the lower Yakima River when it is commingled with large numbers of other smolts (YN, unpublished data, 2000).

Competition:

Temperature-mediated impacts

Competitive pressure from redside shiners (and possibly other Cyprinids) are probably much higher than they would otherwise be if water temperatures in the middleYakima, where shiner densities are very high (Patten and Thompson, 1970), were not unnaturally high.

Juvenile bass

The very high densities of small-mouth bass in the lower Yakima (primarily below Prosser Dam) represents a major competitive obstacle to juvenile fall chinook rearing in the same area.

Pathogens and Parasites

Ceratomyxa shasta has been discovered in upper Yakima spring chinook, and is probably is also present in other species and stocks of Yakima steelhead and salmon. Because virulence increases with water temperature, fall chinook are likely to be most significantly affected.

Mutualism

Beaver have been eradicated from much of the basin, severely impacting base flows in dryer watersheds (e.g., Satus Cr) and eliminating critical rearing and overwintering habitat for fry and presmolts, and for pool-loving species like coho.

Spawning escapements are a small percent of historical values. Therefore the mutualistic effects of increased nutrient concentrations provided by salmon and steelhead carcasses are much lower than they were historically, and the primary productivity and carrying capacity of geologically infertile reaches has been reduced.

The abundance of pacific lamprey is currently very low in the basin. Juvenile salmon feed voraciously on lamprey larvae, which have a very high caloric content, as to larger predators which also prey on smolts. Although the relationship of lamprey and anadromous salmonids is not mutualistic, a scarcity of lamprey adversely affects salmon and steelhead by not partially sating smolt predators and/or diverting their attention away from smolts. Salmonids are also the poorer for not having lamprey as a prey item themselves.

Wildlife

Isolation and fragmentation of native habitat are the biggest factors influencing the long term changes in abundance and distribution of wildlife populations (Buss and Dziedzic 1955; Buss 1964; Swenson et al. 1987; McDonald and Reese 1998).

Wetland and Riparian

Reduction in amount of wetland and riparian habitats
Replacement of native wetland vegetation by exotics
Loss of nutrient cycling (inverts and others)

Northern Leopard Frog *(Rana pipiens)*

Predation by bullfrogs is thought to be a limiting factor (Leonard et al 1993). Waterfowl, fish, aquatic insects and snakes also prey on leopard frogs. Extensive mortality occurs on roadways, especially those built between breeding ponds and other water bodies used by these frogs. Agricultural chemicals and Rotenone kill tadpoles. Land use changes, development and irrigation projects contribute to declines of leopard frogs as well (McAllister et al 1999).

Tailed Frog *(Ascaphus truei)*

Limiting factors are thought to be stream temperature and water quality (Nussbaum et al 1983, Leonard et al 1993).

Western Toad *(Bufo boreas)*

Like other amphibians, environmental changes brought on by human development and disturbances can negatively affect western toads. The loss of wetlands is one factor contributing to the decline of western toads (Leonard et al 1993).

Columbia Spotted Frog *(Rana luteiventris)*

Factors leading to the decline in spotted frogs across the region are not fully understood, nor are the limiting factors for this subbasin. However, the loss and degradation of wetland habitats and the introduction of bullfrogs (*Rana catasbeiana*) are thought to be major factors (Leonard et al. 1993). Habitat fragmentation, long-term overgrazing, and alterations to aquatic systems, such as diversions for irrigation and development around springs also negatively impact spotted frogs (Nordstrom and Milner 1997).

Western Pond Turtle *(Clemmys marmorata)*

The western pond turtle is declining throughout most of its range and is highly vulnerable to extirpation in Washington. Limiting factors are loss of habitat (both aquatic and upland nesting), natural juvenile survival and recruitment, and reproductive and population isolation (Storm and Leonard 1995).

Peregrine falcon *(Falco peregrinus)*

Limiting factors for peregrines are the availability of protected nest sites and adequate prey. Inappropriate pesticides in the environment also limit peregrine populations.

Sandhill Crane *(Grus canadensis)*

Sandhill cranes are in jeopardy of extinction in Washington because of their limited distribution, low numbers, poor breeding success and low colt survival, and loss of shallow marshes or wet meadows for feeding and nesting (Safina 1993). In addition, a large percentage of their wintering habitat is privately owned and subject to potential alteration (Lewis 1980, Pogson and Lindstedt 1991).

Beaver

Although no studies of beaver have been conducted in the subbasin, the likely limiting factors are the availability and quality of riparian and wetland habitats and vegetation.

Waterfowl

Availability of diverse high quality wetlands (Larsen, 1999) may be limiting waterfowl production. In dryland agricultural areas nesting habitat may be limited by agricultural practices and grazing in some areas. Wintering duck numbers are limited by food source availability in the form of cereal grain stubble fields.

Bald Eagle (Haliaeetus leucocephalus)

Factors limiting bald eagles include:

- Human disturbance closer than 300 m at nesting sites
- loss of nesting sites to human activities such as logging or home site development
- Presence of communal roost sites in mature trees adjacent to feeding sites
- Adequate food sources, (such as spawning salmon)
- Impacts to key habitats from activities such as dredging, herbicide or pesticide applications, oil spills, toxic substances, or introduction of exotic species (WDW 1991)

Riparian Migratory Songbirds

It is estimated that 57% of the 118 species of neotropical migrant songbird in North America use riparian habitats while here. This close association indicates the importance of this habitat to this species group.

Factors limiting migratory songbirds associated with riparian areas include:

- Fragmentation of riparian corridors
- Presence of excessive edge, i.e. lack of adequate width to create interior habitat conditions
- Lack of mature overstory cottonwoods, dense shrubby understories and other riparian plant species
- Overgrazing
- Logging of riparian zones
- Land clearing for agriculture, urban or homesite development

Wider riparian buffers appear to result in increased bird use (Knutson and Naef, 1997).

Forest Associated

Canada Lynx *(Lynx canadensis)*

Lynx trapping is no longer permitted in Washington state, and little direct lynx mortality results from trapping and hunting targeted at other species. Lynx recovery is now limited by natural and human-influenced restrictions in habitat distribution (the latter including habitat alteration by pre-commercial tree thinning, commercial timber harvest, and fire exclusion), and competition with coyotes and other predators. Coyotes were once rare in Washington, but their populations exploded once wolves were extirpated (Stinson 2000). Humans also influence this balance between lynx and their competitors by building roads and openings. In winter, these openings allow snow to crust over, and snowmobiles cause further compaction, thus allowing lynx competitors to access lynx habitat (Ruediger 1999). Lynx are highly dependent on snowshoe hares, and fluctuations in populations of this primary prey species (due to natural cycling or habitat alteration) also limit lynx populations.

Wolverine *(Gulo gulo)*

Information regarding wolverines in Washington is limited, but limiting factors are likely: expansive areas of undisturbed coniferous forests, adequate year round food supplies, and large woody debris.

Fisher *(Martes pennanti)*

Information regarding fisher in Washington is limited, but limiting factors are likely: the species' low reproductive rate and density, large diameter snags and logs, and expansive areas of contiguous forested habitat.

Flammulated Owl *(Otus flammeolus)*

Flammulated owls are limited by the availability of Old growth ponderosa pine habitat and insect prey, particularly moths. The use of pesticides in forested environments also limits flammulated owl populations. Availability of suitable nest cavities and/or arthropod prey in ponderosa pine or mixed conifer forests. (WDW 1991)

Northern Goshawk *(Accipiter gentiles)*

The loss of suitable nesting habitat from timber harvest (Reynolds 1989) limits goshawk populations. Other limiting factors include the availability of adequate foraging and post fledging habitat and adequate prey. Human disturbance is also a limiting factor.

Northern Spotted Owl *(Strix occidentalis caurina)*

The loss of suitable habitat to timber harvest, competition with barred owls and disturbance from human activities limits spotted owl populations.

Sharptail Snake *(Contia tenius)*

Information regarding sharptail snakes in the subbasin is limited, but limiting factors are likely to include the availability of moist rotting logs and stable talus slopes near streams and moist habitats (Nussbaum et al 1983) as well as the availability of slugs (Storm and Leonard 1995).

Gray Wolf *(Canis lupus)*

In the Yakima subbasin, wolves are likely limited by extensive areas of contiguous, undisturbed habitat with an adequate year round food supply.

Grizzly Bear *(Ursus arctos)*

The availability of extensive areas of contiguous undisturbed habitat is likely the primary limiting factor for grizzly bears in the Yakima subbasin.

Pileated Woodpeckers *(Dryocopus pileatus)*

Limiting factors include: the abundance of mature and old growth conifer forests, abundance of large diameter snags and logs.

White-headed Woodpeckers *(Picoides albolarvatus)*

Limiting factors include: the abundance of mature ponderosa pine forests and large ponderosa pine snags (WDW 1991).

Black-backed Woodpeckers *(Picoides arcticus)*

Limiting factors include: the availability and abundance of mature and old growth lodgepole pine, ponderosa pine and mixed conifer forest, especially stands impacted by disease and fire, the availability of a beetle prey base, abundance of decayed snags (WDW 1991).

Black Bear (Ursus americanus)

Factors limiting black bear populations in the subbasin have not been well-defined. The reduction and degradation of fringe/ transition habitat (including oak stands and riparian stands) is likely a factor that limits black bears in the subbasin because bears are highly dependent on this habitat type for foraging immediately prior to hibernation (S. McCorquodale, Pers. Comm. 2001). Hunting is a potential factor that could limit black bears in the subbasin as well.

Migratory Songbirds

Factors limiting migratory songbirds associated with forest habitats include:

- Fragmentation of forest stands
- Loss of old growth and mature forests with large tree structure.
- Presence of excessive edge, i.e. lack of adequate depth to create interior habitat conditions
- Lack of mature overstory canopy habitat

Loss of forest land to roads, agriculture, urban or homesite development

Fringe/Transition

Elk (Cervus elaphus)

Limiting factors for elk are the availability and quality of winter range habitats.

Western Gray Squirrel *(Sciurus griseus)*

Limiting factors for western gray squirrels are the availability and quality of oak woodlands and their proximity to water sources. Current threats include loss of habitat from logging, residential development, and invasion of the eastern gray squirrel.

Lewis's Woodpecker *(Melanerpes lewis)*

Limiting factors include: the availability of snags, abundance of mast and insects, and nest holes created by other woodpeckers (WDW 1991).

Shrubsteppe

Reduction in amount of shrubsteppe habitat
Reduction in the amount of deep soil shrubsteppe habitat
Loss of connectivity of shrubsteppe habitat (fragmentation)
Replacement of native shrubsteppe vegetation by exotics
Loss of shrub component (sagebrush, bitterbrush)

Golden Eagle *(Aquila chrysaetos)*

Availability of secluded nest sites, adequate prey located within foraging distance of the nest and minimum nesting territory size are all limiting factors (Beecham and Roberts, 1975). Habitat loss from agricultural and urban conversion, as well as lead poisoning (from hunter kills) or incidental poisoning associated with predator control activities are also limiting factors. Human disturbance on nesting sites can also a major problem, particularly in areas of high recreational (J. McGowan, WDFW, pers. comm.) or commercial (such as rock crushing) use. They are listed in Washington as a state candidate species (WDFW).

Ferruginous Hawk (*Buteo regalis*)

Ferruginous hawks are susceptible to shrubsteppe habitat alteration associated with human disturbance, cultivation and grazing, and with subsequent declines in abundance of prey species, such black-tailed and white-tailed jackrabbits, both currently candidates for listing within Washington due to their low and/or declining abundance (WDFW, 1996). Adult ferruginous hawks have been documented to fly up to 15 km off site to forage for pocket gophers, an smaller alternate prey species (Leary 1996). These long flights to foraging areas may reduce adult nest attendance and potentially may increase mortality of young.

Burrowing Owl (Speotyto cunicularia)

Burrowing owls appear to be declining in the subbasin based on incidental observations and recent inventories (Bartels and Tabor 1999). Some of the declines appear to be related to long-term loss in availability of suitable foraging habitat and/or potential burrows. The decline in number of burrows may be an indirect result of declines of mammals including pygmy rabbits, badgers, and ground squirrels.

Sage grouse (Centrocercus urophasianus)

Sage grouse populations are limited by availability of large expanses of high quality, un-fragmented shrub-steppe habitat, habitat conversion (agricultural and other) and degradation, and population isolation (Hays et al. 1998, Schroeder et al. 2000b).

Migratory Songbirds

Fragmentation has severely reduced habitat for many migratory songbirds. Sage sparrows, for example, are generally found only in blocks of shrubsteppe greater than 1000 ha (2470 acres) (Vander Haegen et al. 2001). Populations of species with small home ranges and limited dispersal capabilities are likely to become isolated and vulnerable to extirpation. Wildlife populations in fragmented habitats also may be more vulnerable to predation. In Washington, Brewer's sparrows, lark sparrows, and sage thrashers had greater nest predation rates in fragmented habitats than in continuous habitats (WDFW, unpublished data).

Pygmy Rabbits (Brachylagus idahoensis)

Pygmy rabbits are limited by widespread loss and fragmentation of shrub steppe (Musser and McCall 2000).

Black-tailed (*Lepus californicus*) and White-tailed (*Lepus townsendii*) Jackrabbits

Although specific factors limiting both jackrabbits species are largely unknown, white-tailed and black-tailed of jackrabbits are closely associated with shrubsteppe habitats, and consequently, have shown some of the same downward trends as other shrub steppe dependent species limited by widespread loss and fragmentation of shrubsteppe habitat.

Migratory Songbirds

Fragmentation has been tied to lower nesting rates, lower nesting success, and greater rates of nest parasitism by brown-headed cowbirds. Further, it appears that certain species are genetically "programmed" to seek large parcels of suitable habitat and do not breed in small patches, even though the patches appear suitable to us. These 'fragmentation effects' are thought to play a part in the observed declines in some species of migratory birds observed over the last few decades.

California Mountain Kingsnake (*Lampropeltis zonata)*

Little is known about this species, including limiting factors.

Striped Whipsnake *(Masticophis taeniatus)*

Little is known about this species, including limiting factors.

Other Shrub Steppe Dependent Species

Nearly all populations of shrubsteppe dependent species in the subbasin have declined along with the availability of quality shrubsteppe habitats. Species are limited by widespread habitat loss due to agricultural and other conversion, fragmentation, competition and invasion by exotic plant species, and fire.

Generalists

Rocky Mountain Mule Deer (Odocoileus hemionus hemionus) and **Black-tailed deer** (Odocoileus hemionus columbianus)

Mule deer and black-tailed deer are limited by the abundance and availability of winter range and riparian habitat (WDW 1991, J. Bernatowicz, Pers. Comm. 2000)

Specialists

Mardon skipper *(Polites mardon)*

Limiting factors for mardon skippers are the loss and degradation of habitat and poor dispersal /geographic isolation. The major causes of habitat degradation/ loss are development, grazing, agriculture, invasion of habitats by non-native plants, natural succession of meadows to shrubland/forest and the use of herbicides. An additional concern for this subbasin has been the use of chemical and biological insecticides, particularly in relation to its use for control of spruce budworm (Potter et al. 1999).

Silver-bordered Bog Fritillary *(Boloria selene atrocostalis)*

The availability of boggy meadows and true bog habitat with adequate populations of violets restricts the distribution of the silver-bordered bog fritillary. Natural succession within these plant communities jeopardizes habitat components necessary for this butterfly. Human activities that alter the water table or reduce floristic diversity, such as land development, wetland drainage, intensive fertilizing and grazing, and pesticide application, also threaten this butterfly's existence (Larsen et al 1995).

Larch Mountain Salamander *(Plethodon larselli)*

Availability of undisturbed, shaded, moist talus slopes is a limiting factor for this species (WDW 1991).

Bats

Studies of abundance, density and life history of bat species have not been conducted in this subbasin, so factors limiting bat populations are not yet known. Contributing factors may include the loss and degradation of habitats and habitat components such as riparian/ wetland habitats and snags for roosting, and the reduction of prey species from such factors as use of insecticides.

Bighorn Sheep *(Ovis canadensis)*

Factors limiting bighorns include disease introduced by domestic sheep, noxious weeds on range, poaching and loss of range to development.

Mountain Goats *(Oreamnos americanus)*

Long-term gradual decline in the statewide population suggests that habitat changes are negatively affecting goat numbers. Fires suppression policies and natural forest succession continue to degrade critical mountain goat foraging habitat. Fire suppression allows conifers to invade meadows and degrade their value for goats. This degradation and loss of alpine meadows, coupled with increasing recreational use and disturbance of alpine habitat are most likely the two greatest negative impacts to mountain goats. If mountain goat populations are to increase, there must be increased use of prescribed fire in mountain meadows, and land use plans that minimize road construction and human disturbance to alpine habitats.

Wildlife Habitats

Forested

Principle limiting factors on forest habitats in the sub basin include:

- Logging: Mature, (including old-growth) forests are the most limited forest habitat type in the Yakima sub-basin, particularly at lower elevations. The principle limiting factor on the occurrence of these habitats is timber harvest. Both dry and wet types, have high economic value, and therefore have been, and continue to be, extremely vulnerable to habitat loss. This has resulted in its limited and fragmented distribution across the landscape (WDFW PHS 1993).
- Fire Suppression: On dry forest types, fire suppression has resulted in drastically changed stand conditions from the historic conditions. Adequate low intensity, high frequency fires in a stand maintaining fire regime have influenced and limited the

presence and development of ecologically sustainable dry forest stands (ICBEMP 1997).

- Roads: There is an extensive network or forest roads throughout the basin. These roads allow human access to forest stands, with the associated timber harvest and snag cutting, thus limiting forest habitat. New construction into remote areas continues on private lands (particularly in the upper sub-basin). The limited success of various road management plans (Green Dot systems, gates) continues to allow for the associated impacts to forests from roads.
- Snag Cutting: Despite bans on snag cutting on many public and private lands, snags are still cut by many firewood gatherers in the Yakima sub basin (C. McKinney, WA DNR pers. comm.) Cutting of snags for firewood is allowed on the Yakama Indian Reservation. Loss of this important habitat attribute is a limiting factor for many forest wildlife species.

Fringe/Transition

Factors that limit the availability and quality of fringe/ transition habitats include:

- Urban development
- Agricultural conversion
- Overgrazing by livestock
- Encroachment of noxious weeds

Winter Range

Factors that limit the availability and quality of deer and elk winter range include:

- over grazing by domestic livestock
- home site development
- agricultural conversion.
- Noxious weeds
- Roads and human disturbance

Oregon White Oak (Quercus garryana)

Factors that limit the availability and quality of Oregon white oak habitats include urban development, stand thinning and land conversion for conifer production, agriculture, fuelwood cutting, cattle grazing and lack of high frequency, low intensity fires (Larsen and Morgan 1998).

Riparian/Wetland

Factors that limit the availability and quality of wetland and riparian habitats include diking, draining, replacement of native plants by exotics, livestock grazing, urban development, and loss of nutrient cycling (salmon, inverts and others).

Shrub Steppe

Factors that limit the availability and quality of shrubsteppe habitat include agricultural conversion (particularly deep soils), urbanization, livestock grazing, development, replacement of native vegetation by exotics, and loss of the shrub component (sagebrush, bitterbrush) due to wildfire and/or herbicides.

Agricultural

Factors that limit the availability and quality of agricultural habitat include loss of woody cover, weedy edges and riparian vegetation along field borders and irrigation canals and drains, increasing isolation of remaining habitats, and interruption of connectivity of habitats e.g. riparian to upland. This interruption is particularly evident with big-game species that are unable to reach winter range in lowland and riparian areas and are thus dependent on feeding programs. Conflicts between wildlife and agricultural uses of land have been addressed by fencing out, trapping, or killing the wildlife. In dryland agricultural areas nesting habitat may be limited by agricultural practices and grazing in some areas.

Artificial Production

Historical Artificial Production

The state of Washington has released salmonids in the Yakima subbasin since the early 1930s. Various releases of spring chinook have been conducted in the Yakima since 1959. Most of these releases were made during the early 1980's as part of a spring chinook research program. It is believed that very little adult production resulted from these releases. The information from these releases is presented in Table 32.

Prior to that various federal and county agencies released fish throughout the subbasin. Facilities operated by the Yakima and Kittitas County Commissioners, one at the current site of the Naches Hatchery and the other in the Kittitas valley were raising trout as early as 1912 and 1915, respectively. Records of fish released prior to about 1932, when the Department of Game was established, generally are very incomplete. The United States Bureau of Fisheries stocked cutthroat from Montana in Yakima County streams as early as 1895 (Crawford 1979). Lampman (1945) reported that a shipment of 5,000 smallmouth bass to the Benton County Commission was released in the Yakima River in 1925 and again in 1934. Since the 1930s most Yakima subbasin lakes, ponds, rivers, and streams have been planted with fish raised at Naches and Yakima hatcheries until Yakima Hatchery closed in 1992.

Table 32. History of spring chinook supplementation in Yakima subbasin.

Release date	Hatchery & Stock	Size #/lb	Number released	Release site	Return rate %
Aug-59	Klickitat (Klickitat)	143 fry	20,000	Upper Yakima	N.D.
May-61	Leavenworth (Icicle)	330 fry	18,000	Upper Yakima	N.D.
Feb-62	Leavenworth (Icicle)	1000 fry	5,000	Upper Yakima	N.D.
Dec-62	Leavenworth (Icicle)	1000 fry	5,000	Upper Yakima	N.D.
1963	N.D.	N.D.	12,500	Nile Springs	N.D.
1964	N.D	N.D.	10,000	Nile Springs	N.D.
Jun-73	Klickitat (Klickitat)	58 fry	162,400	Naches River	N.D.
Jun-73	Klickitat (Klickitat)	58 fry	162,400	Anerucab R.	N.D.
1975	N.D.	N.D.	8,580	Nile Springs	N.D.
Apr-76	Ringold (Ringold)	3 smolt	7,230	Nile Springs	N.D.
Sep-76	Klickitat (Klickitat)	29 parr	42,775	Nile Springs	N.D.
Mar-77	Klickitat (Klickitat)	19 smolt	13,300	Nile - Richland N.D.	N.D.
Mar-78	Klickitat (Cowlitz)	7 smolt	2,462	Nile Springs	N.D.
Apr-79	Carson (Carson)	20 smolt	50,000	Upper Yakima	N.D.
Apr-79	Klickitat (Carson)	12 smolt	25,000	Nile Springs	N.D.
Apr-80	Klickitat (Klickitat)	10 smolt	24,000	Nile Springs	N.D.
Apr-80	Leavenworth (Carson)	18 smolt	30,260	Upper Yakima	N.D.
Apr-81	Klickitat (Klickitat)	14 smolt	33,616	Nile Springs	N.D.
Apr-81	Leavenworth (Carson)	20 smolt	400,221	Upper Yakima	N.D.
Apr-82	Leavenworth (Carson)	14 smolt	100,050	Nile Springs	0.19
Apr-82	Leavenworth (Carson)	14 smolt	401,714	Upper Yakima	0.07
Apr-83	Leavenworth (Carson)	17.6 smolt	99,725	Nile Springs	0.08
Apr-83	Leavenworth (Carson)	19.5 smolt	97,725	Upper Yakima	0.05
Apr-84	Entian (Carson)	19 smolt	29,636	Nile Springs	0.13
Apr-84	Entian (Carson)	25 smolt	42,552	Upper Yakima	0.04
Jun-84	Leavenworth (Carson)	66 fry	102,837	Upper Yakima	0.02
Sep-84	Leavenworth (Carson)	25 parr	102,833	Upper Yakima	0.03
Nov-84	Leavenworth (Carson)	21.6 parr	108,305	Upper Yakima	0.04
Apr-85	Leavenworth (Carson)	18 smolt	45,195	Upper Yakima (pond acc'd)	0.13
Apr-85	Leavenworth (Carson)	21.6 smolt	42,210	Upper Yakima	0.08
Apr-85	Leavenworth (Carson)	11 smolt	25,794	Rattlesnake	0.05
Jun-85	Leavenworth (Carson)	66 fry	100,750	Upper Yakima	N.A.
Sep-85	Leavenworth (Carson)	25 parr	101,724	Upper Yakima	N.A.
Nov-85	Leavenworth (Carson)	22 parr	101,522	Upper Yakima	N.A.
Mar-86	Leavenworth (wild Yak)	17.1 smolt	33,052	Upper Yakima (pond acc'd)	N.A.
Mar-86	Leavenworth (hybid)	17.2 smolt	46,476	Upper Yakima (pond acc'd)	N.A.
Mar-86	Leavenworth (Carson)	20.6 smolt	51,846	Upper Yakima (pond acc'd)	N.A.
Apr-86	Leavenworth (Carson)	19.9 smolt	50,657	Upper Yakima	N.A.
Apr-87	Leavenworth (Carson)	20.6 smolt	50,519	Upper Yakima (pond acc'd)	N.A.
Apr-87	Leavenworth (Carson)	19.9 smolt	50,113	Upper Yakima	N.A.
Apr-87	Leavenworth (hybid)	17.2 smolt	52,392	Upper Yakima (pond acc'd)	N.A.
Apr-87	Leavenworth (wild Yak)	17.1 smolt	56,841	Upper Yakima (pond acc'd)	N.A.

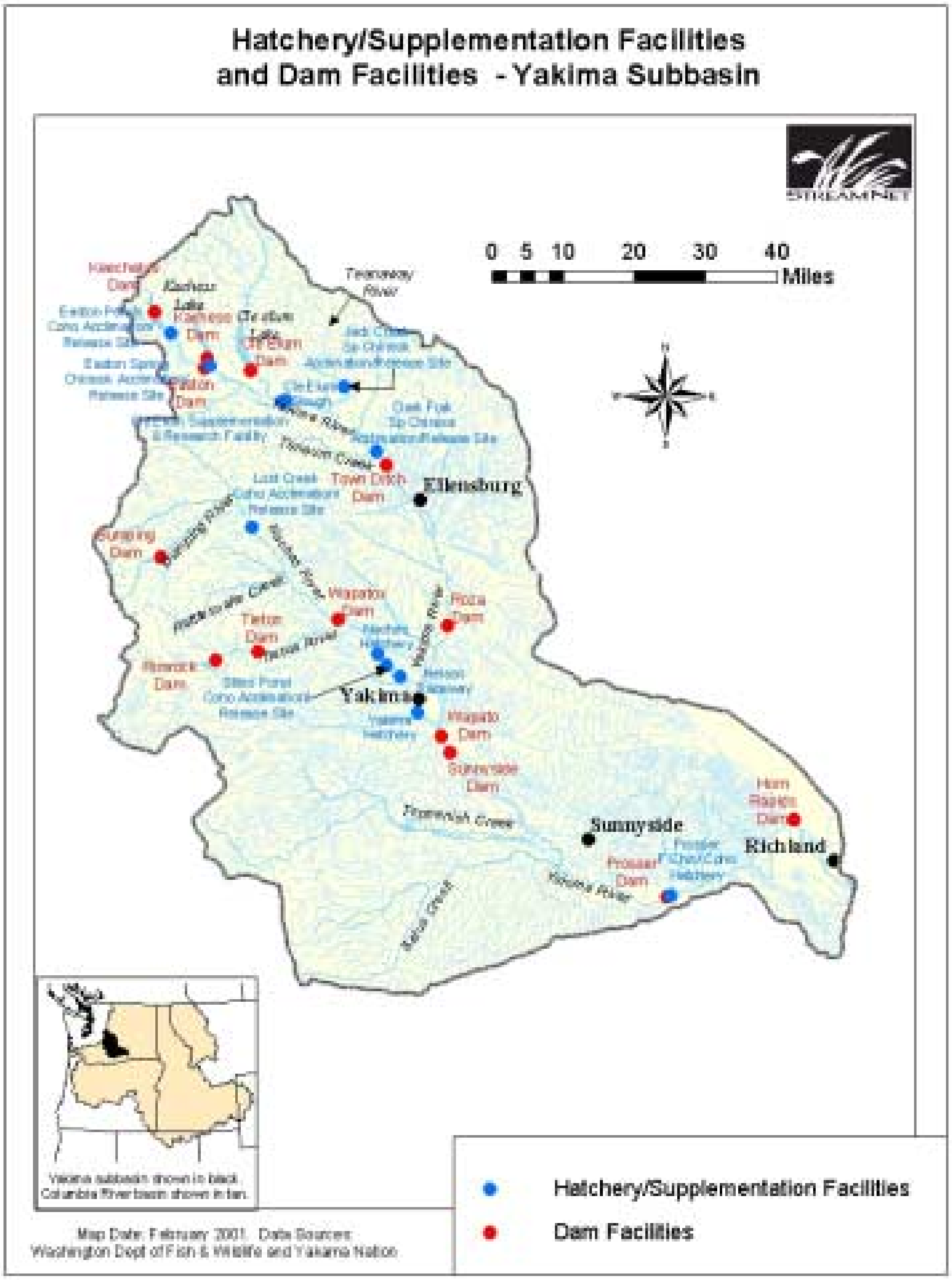


Figure 69. Hatchery and/or supplementation facilities and dams in the Yakima subbasin.

The trout released in the Yakima subbasin the past few decades are generally produced from WDFW broodstocks. Crawford (1979) described the origin and history of WDFW trout broodstocks. Historically, considerable number of South Tacoma and Spokane rainbow trout were released in Yakima Subbasin Rivers and streams. There was a rainbow broodstock at Yakima Hatchery from 1938 to about 1950. Rainbow produced from that brood, which was latter transferred to Goldendale, were planted throughout that subbasin.

Mount Whitney rainbow are planted into high elevation lakes. Rainbow broodstock were also held at Naches Hatchery from 1960 to 1973.

Yakima subbasin fish stocking practices have changed significantly through the years, the most dramatic change in the past two decades has taken place in rivers and streams. For example, in the early 1980's approximately 25,000 catchable-sized rainbow trout were stocked annually in the Yakima River above Roza Dam. No plants have been made in the mainstem Yakima since 1984. Subbasin river and stream plants averaged 68,900 catchable rainbow from 1981-1985. Rivers historically stocked, but no longer stocked are the Naches, American, Little Naches, Bumping, Oak, Ahtanum, Swauk, Teanaway, Cle Elum and Cooper. See Figure 69 for locations of hatchery and/or supplementation facilities in the Yakima basin.

Current Artificial Production – Anadromous

Spring Chinook

The historical distribution of spring chinook is contrasted with current spring chinook distribution in the basin in Figures 70 and 71.

The Yakima/Klickitat Fisheries Project (YKFP) began artificial production of Spring Chinook in 1997 with the completion of the Cle Elum Supplementation and Research Facility. This facility was designed to conduct research on supplementation. The Northwest Power Planning Council stated, "that the purpose of the Yakima/Klickitat Production Project is to test the assumption that new artificial production can be used to increase harvest and natural production while maintaining genetic resources. It also emphasized that careful evaluation of supplementation and employment of adaptive management methods will be needed to accomplish this purpose. Such and approach should add the benefits of learning about supplementation and hatchery systems while contributing to the Council's goal of increasing salmon and steelhead runs in the Columbia River Basin" (NPPC 1990).

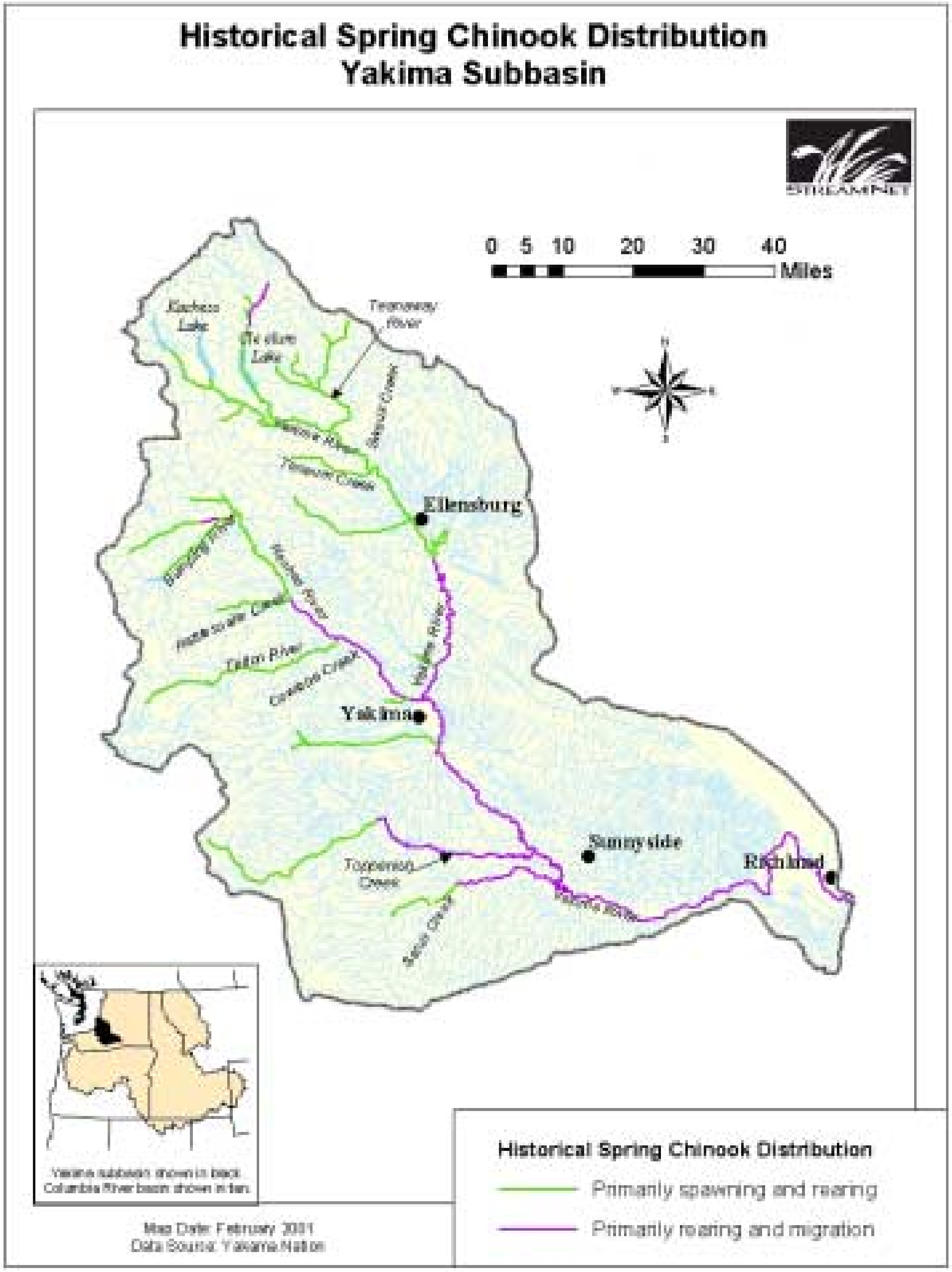


Figure 70. Historical spring chinook distribution in the Yakima subbasin

Adult spring chinook salmon are collected at the Adult Collection and Monitoring Facility located at Roza dam. Adults are randomly collected throughout the duration of the spawning migration. Initially it was decided that no hatchery-returning adults would be used for brood stock. Some experimental crosses between hatchery and wild fish will be done to evaluate domestication selection. It was also determined that no more than fifty percent of the total wild run could be taken into the hatchery for brood stock. This will insure that there will always be natural spawning occurring in the river.

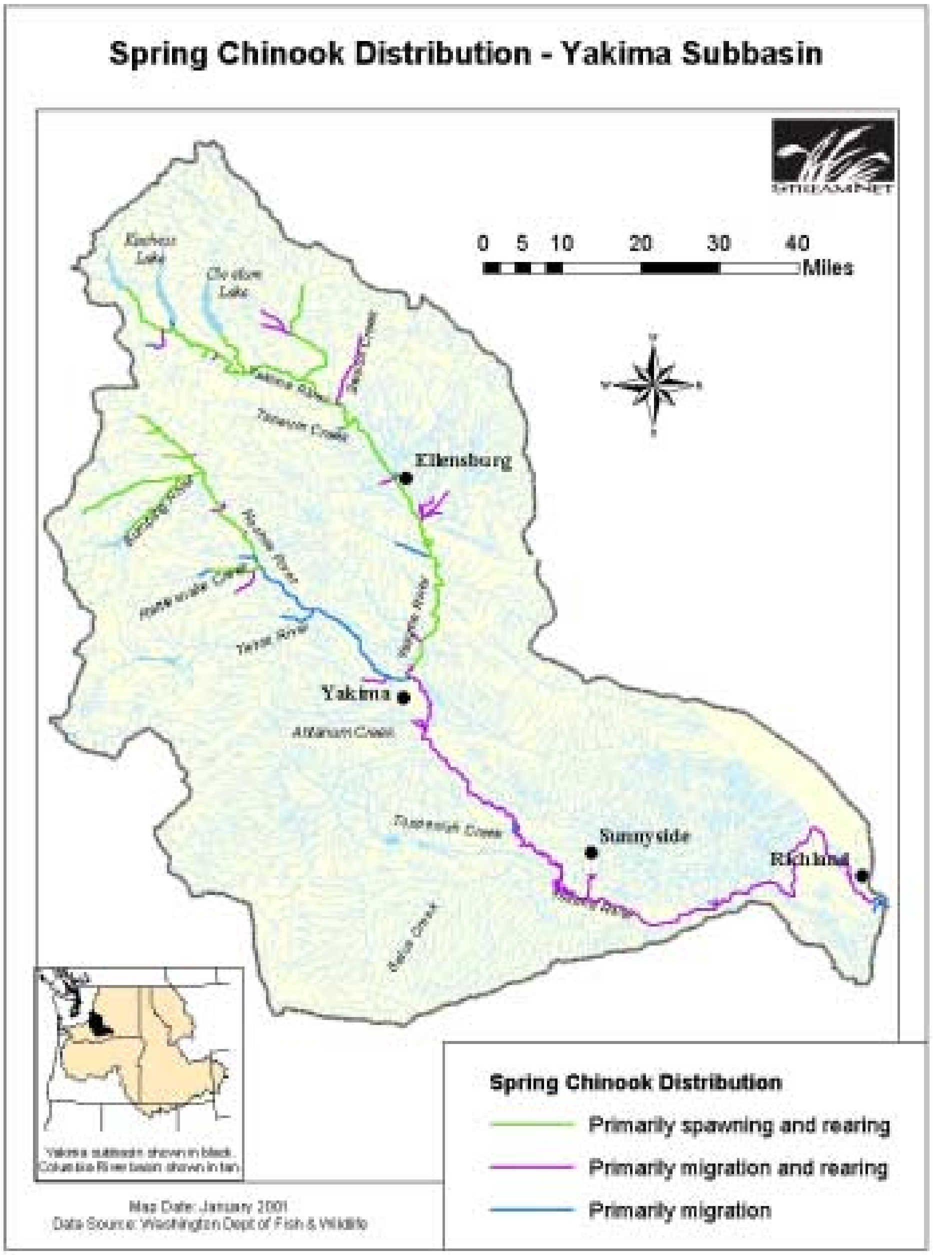


Figure 71. Current spring chinook distribution in the Yakima subbasin

Upon selection for brood stock, the adult salmon are measured, weighed, PIT tagged and transported by truck to the supplementation facility at Cle Elum. The adults are held in ponds through the summer.

Spawning is done in September and early October. All adults are identified by their PIT tag code, DNA samples are taken, fish health samples are collected by USFWS, and the female's eggs are collected. Each females egg complement is divided into three equal components, and each of these is fertilized with the sperm from a separate male. The eggs are mixed together and incubated. At the eyed stage the eggs are divided into two groups, the control and treatment, for experimental purposes.

Table 33. Adult spring chinook spawning in 1997 in the Yakima subbasin

	FISH TRANSFER IN	LOSS BEFORE 1st. SORTING SEPT.2nd	% LOSS BEFORE 1st. SORTING	LOSS AFTER 1st. SORTING	%LOSS AFTER SORTING	% TOTAL LOSS	KILLED	FISH TRANSFER	SPAWNED FISH	GREEN SPAWNED	TOTAL EGG TAKE	EGGS PER FEMALE	EGG LOSS	% EGG LOSS	SMOLTS RELEASED	%EGG TO SMOLT RELEASE
MALE	114			8	7.00%	7.00%			106							
FEMALE	147			14	9.50%	9.50%			133		499817	3758	35457	7.10%	389273	77.90%
JACK	0					8.40%										
TOTAL	**261**			**22**		**7.60%**			**239**			**3758**	**35457**	**7.10%**		

BKD positive females were reared and 7252 were killed as smolts at the Easton Acclimation Site.

Table 34. Adult spring chinook spawning in 1998 in the Yakima subbasin

	FISH TRANSFER IN	LOSS BEFORE 1st. SORTING AUG.31st.	% LOSS BEFORE 1st. SORTING	LOSS AFTER 1st. SORRTING	%LOSS AFTER 1st. SORTING	% TOTAL LOSS	KILLED	FISH TRANSFER	SPAWNED FISH	GREEN SPAWNED	TOTAL EGG TAKE	EGGS PER FEMALE	EGG LOSS	% EGG LOSS	SMOLTS RELEASED	%EGG TO SMOLT RELEASE
MALE	181	5	2.80%	26	14.80%	17.10%			150							
FEMALE	227	9	4.80%	18	8.30%	11.90%			195	2	738427	3788	73431	9.90%	605186	81.90%
															*notation	
JACK																
TOTAL	**408**	**14**	**3.40%**	**44**	**11.20%**	**14.20%**			**345**	**2**	**738427**	**3788**	**73431**	**9.90%**		

* Three BKD positive females were removed from the population before total egg take. 21425 smolts died as a result of loss of water at the Jack Creek Acclimation Site.

Table 35. Adult spring chinook spawning in 1999 in the Yakima subbasin

	FISH TRANSFER IN	LOSS BEFORE 1st. SORTING SEPT.1	% LOSS BEFORE 1st. SORTING	LOSS AFTER 1st. SORTING	%LOSS AFTER 1st. SORTING	% TOTAL LOSS	KILLED	FISH TRANSFER	SPAWNED FISH	GREEN SPAWNED	TOTAL EGG TAKE	EGGS PER FEMALE	EGG LOSS	% EGG LOSS	SMOLTS RELEASED	%EGG TO SMOLT RELEASE
MALE	141	3	2.10%	6	4.30%	6.40%	15	9	107	1						
FEMALE	252	12	4.80%	8	3.30%	7.90%		7	216	3	880081	4074	46692	5.30%	758252	86.20%
															*notation	
JACK	346	9	2.60%	18	5.50%	7.80%	28	162	128	1						
TOTAL	**739**	**24**	**3.20%**	**32**	**4.50%**	**7.60%**	**43**	**178**	**451**	**5**	**880081**	**4074**	**46692**	**5.30%**		

* Six BKD positive females were removed from the population

Table 36. Adult spring chinook spawning in 2000 in the Yakima subbasin

	FISH TRANSFER IN	LOSS BEFORE 1st SORTING SEPT.5	% LOSS BEFORE 1st. SORTING	LOSS AFTER 1st. SORTING	%LOSS AFTER 1st. SORTING	% TOTAL LOSS	KILLED	FISH TRANSFER	SPAWNED FISH	GREEN SPAWNED	TOTAL EGG TAKE	EGGS PER FEMALE	EGG LOSS	% EGG LOSS	SMOLTS RELEASED	%EGG TO SMOLT RELEASE
MALE	198	4	2.00%	16	8.20%	10.10%	13	13 (1)	151							
FEMALE	326	18	5.50%	17	5.30%	10.70%		12(1)	247		1000324	4050	64917	6.50%		
JACK	41	1	2.40%	5	12.50%	14.60%	14	3	19							
TOTAL	**566**	**23**	**4.10%**	**38**	**7.00%**	**10.80%**	**27**	**28(2)**	**417**		1000324	**3598**	**64917**	**6.50%**		

* 31 BKD positive females were removed from the population before total egg take.

The fry are ponded in March and reared in the control or Optimum Conventional Treatment (OCT) group or the Semi Natural Treatment (SNT) group. OCT consists of juvenile hatchery rearing conditions that have been shown to be successful at various state tribal and federal hatcheries in the Northwest. The SNT treatment has the same densities, flows, etc as the OCT but also has raceway walls painted to resemble natural stream conditions, overhead cover, instream cover (submerged Christmas trees), and underwater feeders. There are nine raceways that are designated as OCT and nine are for the SNT fish. There are about 45,000 juveniles reared in each raceway. The experiment is designed to determine if these more natural rearing conditions can improve survival and behavior of the juveniles.

The juveniles are marked in the fall, with about 10% receiving PIT tags and all fish receiving coded-wire tags (CWT) that are placed in different body locations. These CWT fish can then be identified without sacrificing the experimental fish to recover the tags. The CWTs are coded so that each group (raceway) has its own code for identification of carcasses on spawning grounds.

The juveniles are transported to three acclimation sites in late January or early February. Each of the acclimation sites has six raceways, with three OCT and three SNT. The fish are confined in the acclimation raceways for six weeks then allowed to volitionally release for migration out of the subbasin. The smolts are monitored for PIT tags at various dams on their migration corridor to the ocean. Post release survival is calculated from these various detections.

All adults returning to the upper Yakima can be identified at the Roza adult monitoring facility. Thus survival rates of returning adults can be determined at that facility. There is monitoring of harvest in the Yakima to collect any tag information of fish caught below Roza dam. YKFP managers are also requesting that other harvest monitors (in ocean and Columbia River) report tag information to the project.

The supplementation process for adult spring chinook spawning from 1997-2000 is summarized in Tables 33-36.

Table 37 presents the number of broodstock collected for each year, the number of surviving broodstock that were spawned, the estimated (paper) number of eggs produced, the number of juveniles ponded, the number of smolts leaving the acclimation ponds and the number of adults returning. In 2000, only jacks (one ocean adults) had returned to the Yakima. In 2001 most of the adults produced from the first spawning will return.

Table 37. Cle Elum brood SRF spring chinook

Brood Year	Collected at Roza	Actual Spawners	'Paper' Fecundity	Live Egg Count	No. of Fry Ponded	Pre-smolts Tagged	Accl. Exit Counts	Adult Returns (Roza Dam+ Harvest)			
								Age-3	Age-4	Age-5	Total
1997	261	238	537,183			387,938	n/a	740			
1998	408	336	788,332		660,470	615,807	598,882				
1999	738	435	938,497		759,415	765,786					
2000	567	448	1,020,569	870,490							

Coho

Coho salmon were historically present in most tributaries and the upper mainstem of the Yakima and Naches rivers (Figure 72). Coho salmon probably went extinct in the Yakima River in the early 1980s (YN 1997). Efforts to restore coho within the Yakima, therefore, depend largely upon releases of hatchery coho.

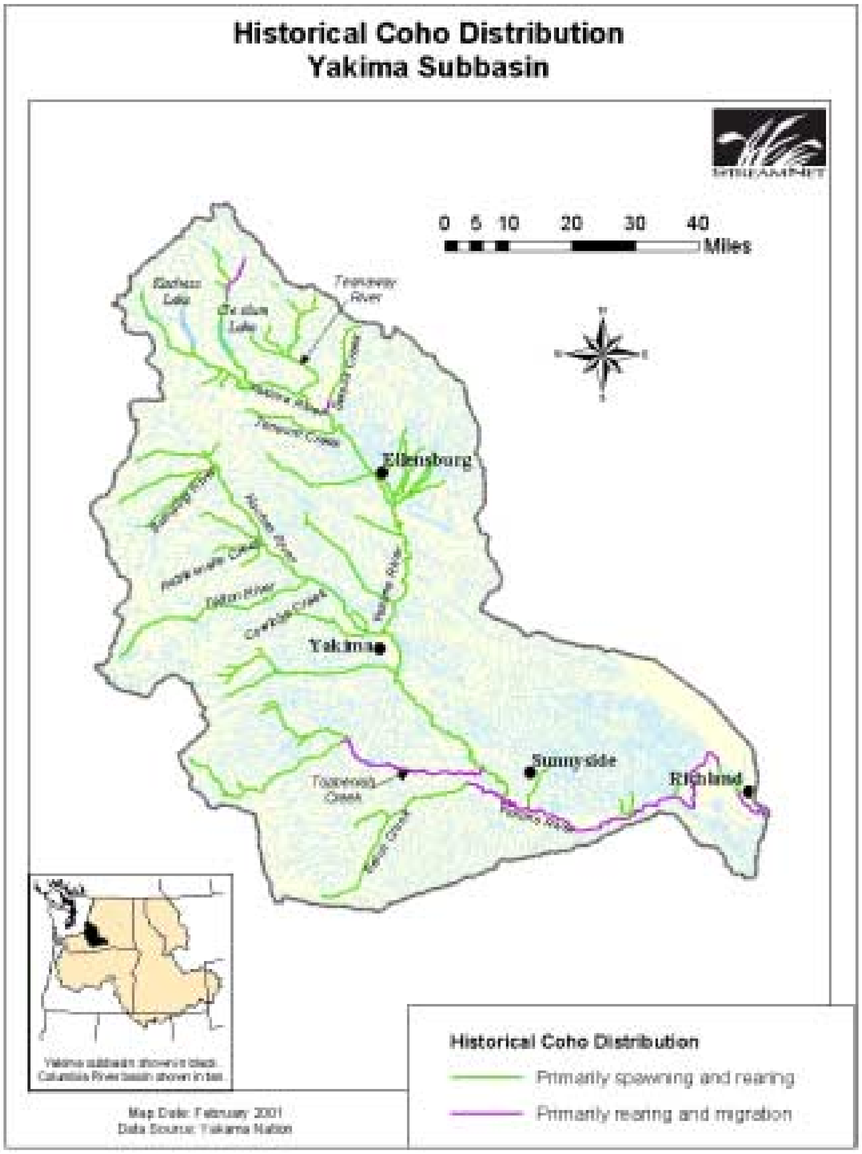


Figure 72. Historic coho distribution in the Yakima subbasin

Beginning in 1985, the Yakama Nation began releasing from 85,000 to 1.4 million coho smolts annually from lower Columbia River hatcheries into the Yakima. Table 38 lists the year of release, the number of smolts released, the sites of release, the smolt survival to Prosser, and the adult returns from those releases. Initially these smolts were trucked directly from the lower Columbia River Hatcheries and released directly in to the Yakima. Beginning in 1993 these smolts were acclimated in various side channels and irrigation drains in the lower Yakima River (below Union Gap).

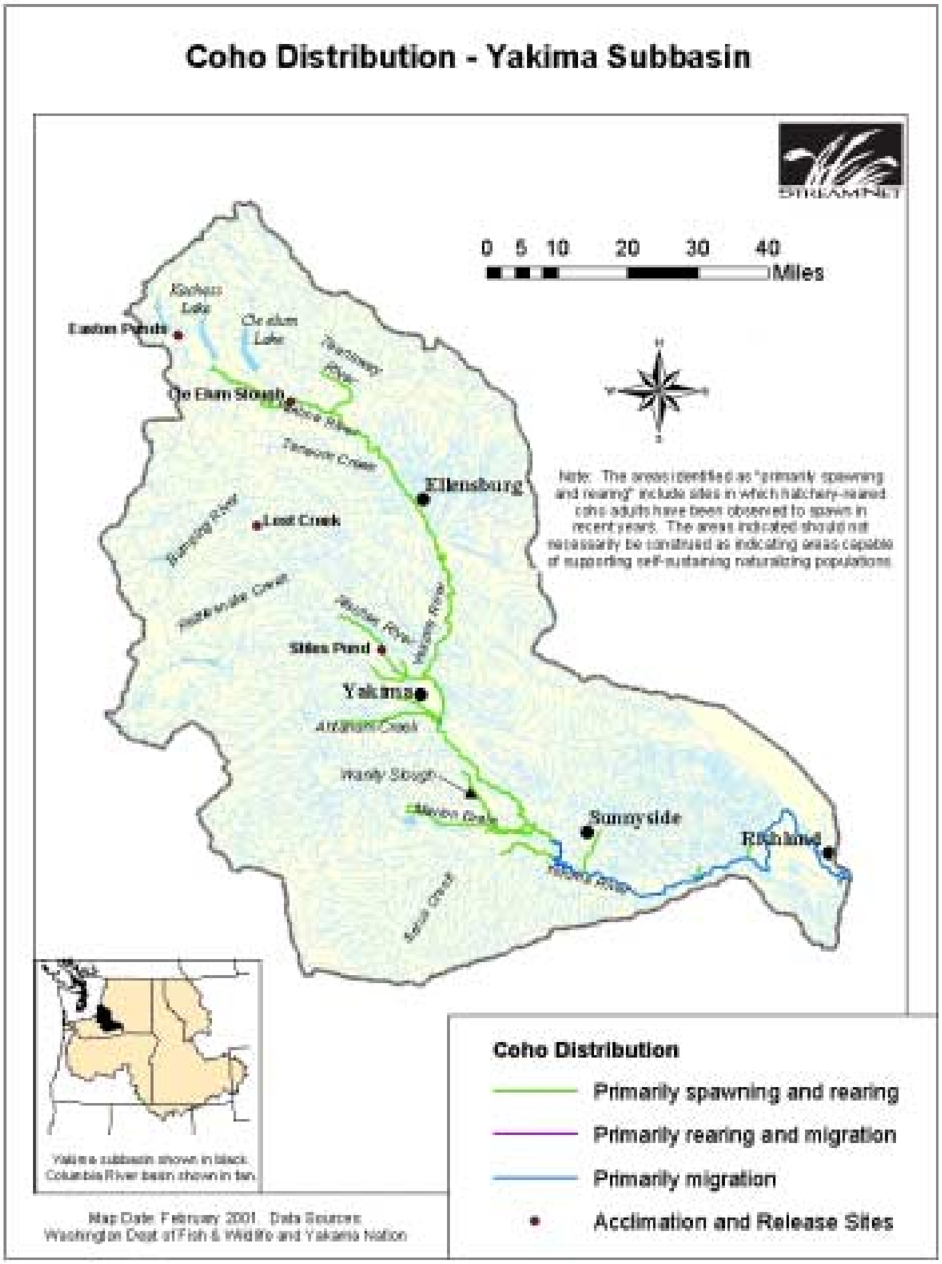


Figure 73. Current coho distribution in the Yakima subbasin

Prior to 1995, the primary purpose of these releases was harvest augmentation. After 1995, the primary purpose became a test of the feasibility of re-establishing natural production. Therefore, after 1995 the acclimation sites were moved to the upper Yakima and Naches Rivers. The feasibility of re-establishing coho in the Yakima basin may initially rely upon the resolution of two central issues: the adaptability of a domesticated lower river coho stock used in the re-introduction efforts and associated survival rates, and the ecological risk to other species associated with coho re-introduction efforts. The feasibility will be discussed in more detail in the Research, Monitoring and Evaluation section.

Currently, the Yakima coho program is part of the Yakima Klickitat Fisheries Project (YKFP). Current artificial production of coho occurs at two different locations. The out of basin smolts are spawned and reared at the lower Columbia River hatcheries, and transported to the acclimation ponds in the upper Yakima and Naches Rivers prior to release. Most of these facilities have a lengthy history of coho propagation activities, which may have the potential to subject these stocks to genetic changes due to selective effects. Such changes are termed domestication selection (Busack et al. 1997). The locally adapted coho smolts are produced from adult returns of previous hatchery smolt releases. These returning adults are collected for brood stock at Prosser dam, and spawned at the Lower Yakima Hatchery Facility located adjacent to the fish screens and juvenile monitoring facility on Chandler canal. These juveniles are reared for one year at the raceways at the Lower Yakima Hatchery, and transported to the acclimation sites for release.

The in-basin and out-of-basin smolts are differentially tagged and are mixed together in the acclimation ponds. The smolt outmigration survival and adult returns are monitored for the two groups to determine if there are differences in survival.

The genetic composition of the endemic and now extinct Yakima River coho is unknown, however it is likely that genotypic differences existed between the lower Columbia River hatchery coho and the original endemic stock. It is possible that phenotypic differences between endemic Yakima River coho populations and lower Columbia coho populations may have included maturation timing, run timing, stamina, or size of returning adults. If coho re-introduction efforts in the Yakima Basin are to succeed, lower Columbia River coho stocks must possess sufficient genetic variability to allow phenotypic plasticity to respond to differing selective pressures between environments of the lower Columbia River and the Yakima River.

Thus the development of a localized broodstock may ultimately determine if this project successfully reestablishes self -sustaining populations of coho in the Yakima River. Figure 73 indicates the current distribution of coho stocks in the Yakima basin.

Table 38. Smolt-to-smolt and smolt-to-adult survival statistics for hatchery coho released in the Yakima basin

Year	Smolts Released	Chandler Passage	Smolt Survival To CJMF (%)	Adult Returns (Year+1) Jacks (Year+0)	Smolt-Adult Survival (%)	Release Dates	Release Sites A = acclimated
1985	260,690	117,558	45.1	230 (0)	0.088	5/28-5/31	Yakima River above Wapato Dam (unacclimated)
1986	84,879	48,349	57.0	82 (0)	0.100	4/1-5/23	Nile Pond on upper Naches River, volitional release A
1987	492,415	193,777	39.4	18 (1)	0.004	4/1-4/20	Wapato Dam + mid-Yakima tributaries (MYT's: Ahtanum, Wide Hollow & Cowiche Creeks)
1988	828,269	606,926	73.3	282 (0)	0.034	4/29-5/7	MYT's
1989	700,186	224,670	32.1	289 (9)	0.043	3/9-3/16	MYT's
1990	505,263	158,305	31.3	230 (0)	0.046	3/9-3/14	MYT's
1991	483,256	112,975	23.4	137 (39)	0.036	3/5-3/16	MYT's + Wanity Slough & Toppenish Cr
1992	631,358	110,999	17.6	162 (53)	0.034	3/1-3/7	MYT's
1993	534,246	82,589	15.5	532 (3)	0.100	3/15-3/17 & late April	MYT's + Wapato & Horn Dams, lower Satus & Toppenish Cr.'s, Granger Pond & Roza WW #3 (WW#3, Granger Pond & Wapato Dam A; the rest unaccl.). Unaccl. releases in March, A in late April.
1994	772,551	403,774	52.3	650 (28)	0.088	4/29	Granger Pond, Roza Wasteway #3, Wapato Dam A
1995	699,474	411,733	58.9	921 (75)	0.142	4/26	Granger Pond, Roza Wasteway #3, Wapato Dam A
1996	1,218,221	785,978	64.5	1241 (417)	0.136	4/10 & 5/6-5/15	Roza Wasteway #3 (May release), Granger Pond (April 10 release) A
1997	1,040,602	306,520	29.5	4625 (71)	0.451	5/15	Roza Wasteway #3, Lost Cr. Pond on the Naches A
1998	1,400,00	472,820	33.8	3532 (54)	0.256	5/15 & 5/30	Roza Wasteway #3, Lost Cr. Pond, Golf Course Springs, and Greenway Pond A
1999	1,030,000	117,107	11.7	N/A (411)	N/A	5/17 & 5/27	Stiles Pond & Lost Creek (Naches); Jack Cr. & Easton Accl. sites & Cle Elum Hatchery Slough (upper Yakima) A

Returns are adult returns 1 year following the released year plus jacks the year of the release. Years in the table represent year of smolt released year plus jacks the year of the release. Years in the table represent year of smolt release.

Fall Chinook

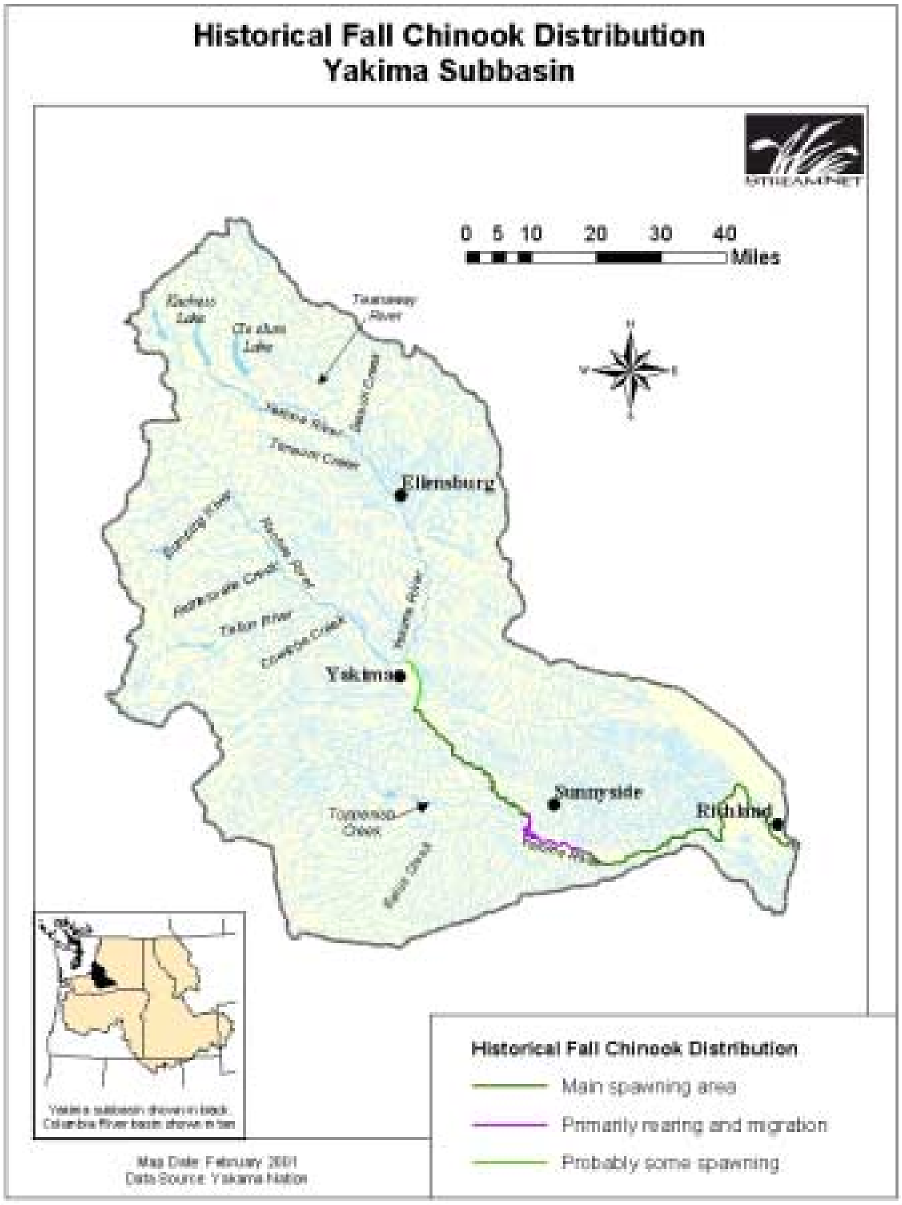


Figure 74. Historical fall chinook distribution in the Yakima subbasin

Figures 74 and 75 contrast historical and current fall chinook distribution in the Yakima basin. Fall chinook escapement is estimated in Figure 76.

The Yakama Nation began releasing hatchery upriver bright fall chinook into the Yakima subbasin in 1983. These releases have been a mixture of direct plants into the Yakima River, and acclimation in net pens (Wapato Canal), various sloughs and irrigation waste return canals. Table 39 presents data on year of release, total fall chinook smolts release, location of release, and any data that could be collected on smolt survival and adult harvest in the ocean and Columbia River. Actual counts of adult returns for fall chinook salmon are complicated by the fact that this species spawns in the entire lower Yakima subbasin, and the adult counting facility is located at Prosser dam which is at River Mile 47. Thus, unless we can develop methods of counting fish lower in the subbasin we will continually face this problem of incomplete fall chinook counts. Spawning ground surveys have also been incomplete, because the depth of spawning, and the lack of clarity of the lower Yakima water have made visual counts difficult to impossible. Some new technologies have potential for improving redd counts in the future.

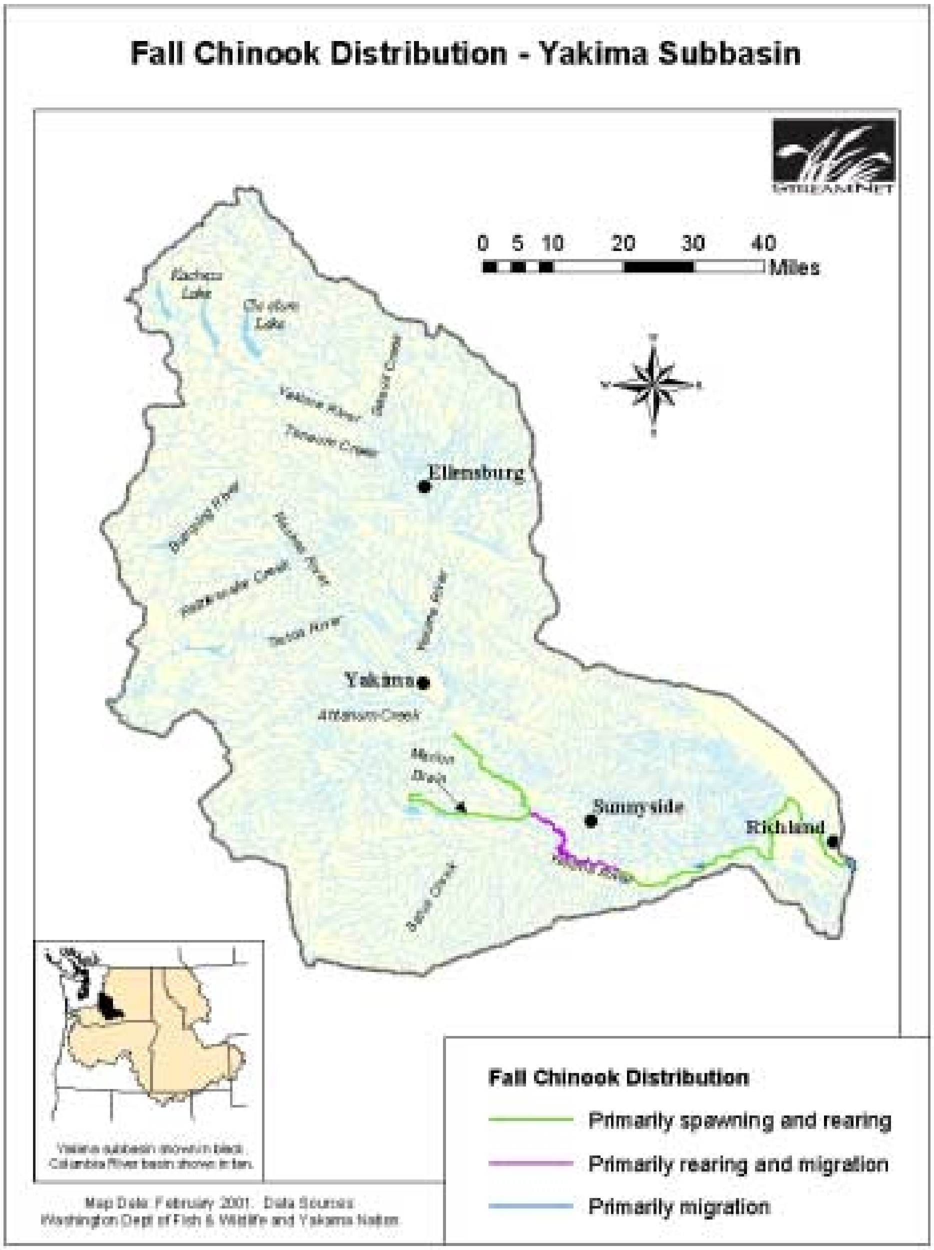


Figure 75. Current fall chinook distribution in the Yakima subbasin

In 1996 the Yakama Nation constructed the Lower Yakima Supplementation and Research Facility at Prosser dam. Three ponds were constructed for acclimation and release of fall chinook at that facility. From 1996 on, the Yakama Nation has collected adult broodstock at Prosser dam and used their progeny for smolt releases (Table 40).

Table 39. Summary of historic releases of hatchery fall chinook smolts made in the Yakima between 1983 and 1996, after which the program was modified to incorporate Yakima and Marion Drain NORs smolts

Year	Hatchery Plants Above Prosser		Hatchery Plants Below Prosser		Hat. Smolt Survival To Prosser, Pen Reared Fish Only (%)	Hat. Smolt Survival To Prosser, Direct Releases Only (%)	Catch Rate In Oceanic And Columbia River Fisheries (% Of No. Tagged Fish Released)
	No.	% Clipped	No.	% Clipped			
1983	0	N. A.	323,796	0	N. A.	N. A.	NO DATA
1984	105,097 (Sunnyside Dam)	100 (98.8% tagged)	479,556 (84.6% Horn, 15.4% Prosser)	21.5 (all Horn; 99,522 tagged)	N. A.	27.1	.09%
1985	100,655 (Sunnyside Dam)	100 (100% tagged)	1,763,500 (52.4% Horn, 47.6% Prosser)	6.1 (all Prosser, all tagged)	N. A.	15.7	PROSS = .09% SUNNY = 0.0%
1986	97,460 (Sunnyside Dam)	100 (96.1% tagged)	1,547,700 (53.2% Horn, 46.8% Prosser)	6.5 (all Prosser, all tagged)	N. A.	32.2	PROSS = .03% SUNNY = 0.0%
1987	196,980 (Sunnyside Dam)	100 (100% tagged)	872,609 (all Prosser)	22.6 (all Prosser, all tagged)	N. A.	44.4	PROSS = .15% SUNNY = .09%
1988	444,795 (55.3% Wapato net pens, 44.7% Sunnyside Dam)	100 (100% tagged)	1,375,888 (all Prosser)	14.5 (all Prosser, 95.6% tagged)	22.6	6.7	PENS = .001% PROSS = .005% SUNNY = 0.0%
1989	540,198 (63% Wapato net pens, 37% Sunnyside Dam)	90.6 (85% Wapato fish clipped and tagged; 100% Sunnyside fish clipped and tagged)	1,430,316 (24% Horn, 76% Prosser)	14.0 (18.4% Prosser fish clipped and tagged; 0% Horn fish clipped and tagged)	18.5	8.7	PENS = .001% SUNNY & WAPATO = .0005%
1990	679,714 (70.6% Wapato net pens, 29.4% Sunnyside Dam)	45.6 (39.9% Sunnyside fish clipped and tagged; 50% Wapato fish clipped, 48% Wapato fish clipped and tagged)	880,344 (all Prosser)	9.2 (9.2% Prosser fish clipped and tagged)	38.0	33.9	PENS = .05% PROSS & SUNNY = .05%
1991	478,916 (Wapato net pens); 1,152,829 (Roza WW #3)	100% Wapato fish clipped and tagged; all of the Roza WW#3 fish were ventral clipped, but none were tagged.	0	N/A	35.0	31.4	PENS = .04%
1992	0	N/A	0	N/A	N/A	N/A	No Data

Year	Hatchery Plants Above Prosser		Hatchery Plants Below Prosser		Hat. Smolt Survival To Prosser, Pen Reared Fish Only (%)	Hat. Smolt Survival To Prosser, Direct Releases Only (%)	Catch Rate In Oceanic And Columbia River Fisheries (% Of No. Tagged Fish Released)
	No.	% Clipped	No.	% Clipped			
1993	165,428 Frontage Rd.	98.5% tagged, 100% clipped	582,731 Prosser ?	98.5% tagged, 100% clipped	N/A	5.5	.005%
1994	0	N/A	1,703,892 Prosser Hatch.	11.6%	N/A	N/A	.001%
1995	0	N/A	1,694,188 Prosser Hatch.	11.7%	N/A	N/A	NO DATA
1996	0	N/A	1,885,504 Prosser Hatch.	10.6%	N/A	N/A	NO DATA

Table 40. Summary of Yakima and Marion Drain hatchery fall chinook released in the Yakima Basin, 1997-2000

Release Year	Little White Salmon	Yakima Stock	Marion Drain Stock
1997	1,700,00	0	1,200
1998	1,700,00	0	7,000
1999	1,700,00	193,000	11,800
2000	1,700,00	200,000	16,000

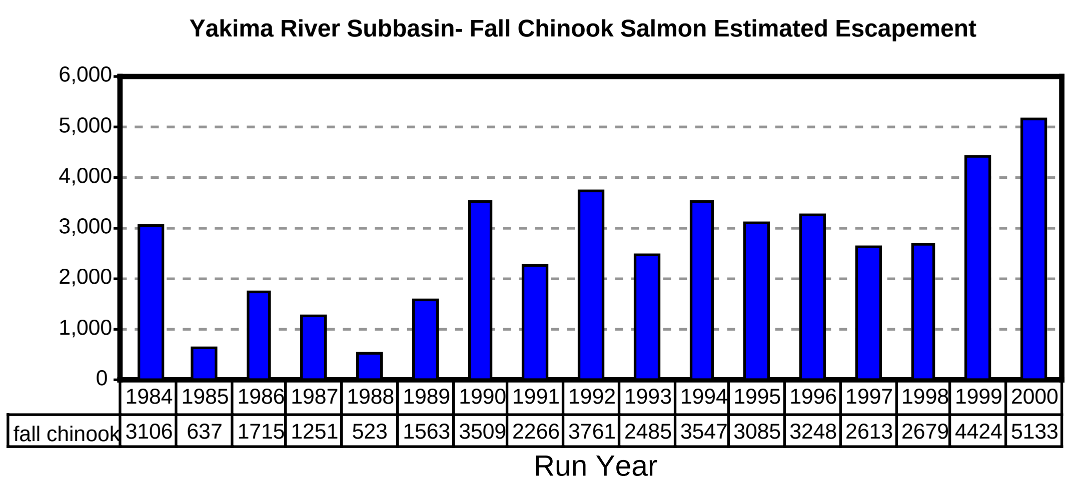


Figure 76. The estimated fall chinook run to the Yakima Basin (includes below Prosser Dam), 1984-2000

Steelhead

While steelhead are no longer stocked in the Yakima Basin, over the years several steelhead stocks were introduced, most notably the Skamania stock, a lower Columbia River stock from the Washougal River. In the 1990s the state changed its policy to allow only in-basin stocks to be used. After that, most releases were produced from wild Yakima fish and were for research to evaluate survival, migration timing and species interaction in the upper Yakima. Table 41 presents hatchery steelhead releases from 1977-1994. After the research was concluded, the steelhead planting programs were terminated. Figure 77 shows current summer steelhead distribution in the basin.

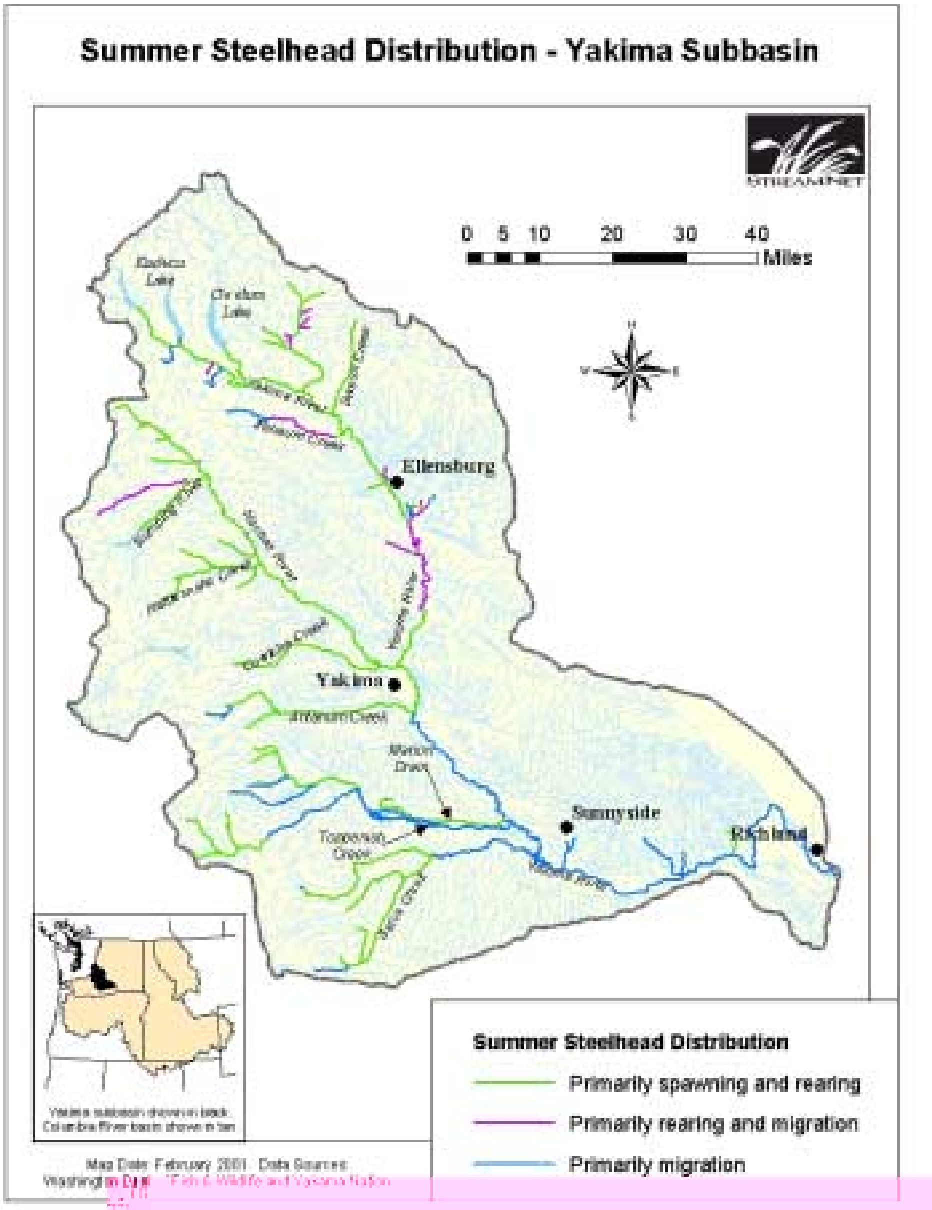


Figure 77. Steelhead distribution in the Yakima subbasin

Table 41. Steelhead releases in artificial production

RELEASE YEAR	MONTH	BROOD	HATCHERY	SIGHT	RIVER MILE	POUNDS RELEASED	SIZE (#/lb)	NUMBER RELEASED
1977				Nelson Sp.				57,570
1978								71,330
1979								61,500
1980								64,745
1981								77,140
1982								52,216
1983								64,810
1984								49,289
1985								88,484
1986								108,630
1987								85,395
1987				Little Naches				56,385
1988								97,915
11 year Total								**935,409**
1989	March	1988	303	Little Naches	3.4	2786	8.3	23,123
1989	April	1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	88.5	11.3	1,000
1989		1988	307		3.4	1067	11.3	12,058
Subtotal								**43,181**
1989	March	1988	303	Toppenish Cr.	44.2	1080	9.2	9,936
1989		1988	303		44.2	2494	9.2	22,944
1989	April	1988	307		44.2	17	10.6	180
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	94.3	10.6	1,000
1989		1988	307		44.2	1109	10.6	11,759
1989	November	1989	307	Wide Hollow Cr.	2	8	248	1,984
Subtotal								**54,803**
GRAND TOTAL								**97,984**
1990	April	1989	304	Naches R	?	7178	4.5	32,301
1990		1989	304		?	2683	9	24,147
1990		1989	307		26	733.3	9	6,600

1990	May	1989	307		8	1040	12	12,480
1990		1989	307		26	425	9	3,829
1990	June	1989	307		?	11004	6.8	74,827
Subtotal								**154,184**
1990	May	1989	307	Wide Hollow Cr.	2	1610	11.2	18,032
Subtotal								**18,032**
1990	April	1989	307	Yakima R	40	226	12	2,712
1990	May	1989	307		40	167	12	2,004
1990		1989	307		40	167	12	2,004
Subtotal								**6,720**

GRAND TOTAL	**178,936**

1991	February	1990	307	Ahtanum Cr.	?	60	117	7,020
1991		1990	307		?	95	42	3,990
1991		1990	307		?	565	28	15,820
Subtotal								**26,830**
1991	May	1990	304	Jungle Cr.	0.5	580	5.8	3,364
1991		1990	304		0.5	845	5.8	4,901
1991		1990	304		0.5	1165	5.8	6,757
1991		1990	304		0.5	800	5.8	4,640
1991		1990	304		0.5	1100	5.8	6,380
1991		1990	304		0.5	550	10	5,500
Subtotal								**31,542**
1991	April	1990	304	NF Teanaway R.	1	44.8	5.8	260
1991		1990	304		1	44.8	5.8	260
1991		1990	304		1	43.1	5.8	250
1991		1990	304		1	43.8	5.8	254
1991		1990	304		1	43.1	5.8	250
1991		1990	304		1	43.1	5.8	250
1991	May	1990	304		1	43	5.8	250
1991		1990	304		1	43	5.8	250
1991		1990	304		1	43	5.8	250
1991		1990	304		1	43	5.8	250
Subtotal								**2,524**
1991	February	1990	307	Wide Hollow Cr.	2	60	117	7,020
1991		1990	307		2	75	42	3,150
1991		1990	307		2	516	28	14,448
1991	June	1990	307		2	900	12.4	11,160
Subtotal								**35,778**
1991	April	1990	304	Yakima R.	17	795	5.8	4,611
1991		1990	304		128	85.5	5.8	496
1991		1990	304		128	85.5	5.8	496
1991		1990	304		128	85.5	5.8	496
1991		1990	304		128	85.5	5.8	496
1991		1990	304		128	85.5	5.8	496
1991		1990	304		128	85.5	5.8	496
1991	May	1990	304		17	800	5.8	4,640
1991		1990	304		17	870	6	5,220
1991		1990	307		11	1000	9.4	9,400

1991		1990	307		11	1175	9.4	11,045
1991		1990	307		11	935	9	8,415
1991		1990	304		80	90.2	5.5	496
1991		1990	304		82	90.2	5.5	496
1991		1990	304		82	90.2	5.5	496
1991		1990	304		82	78.2	5.5	430
1991		1990	304		82	90.2	5.5	496
Subtotal								**48,721**
1991	May	1990	304	Jungle Cr.	0.5			31,542

GRAND TOTAL	**176,937**

1992	May	1991	304	Jungle Cr.	0.5	440	6	2,640
1992		1991	304		0.5	960	6	5,760
1992		1991	304		0.5	1100	6	6,600
1992		1991	304		0.5	1125	6	6,750
1992		1991	307		0.5	505	8.5	4,293
1992		1991	307		0.5	1080	8.5	9,180
Subtotal								**35,223**
1992	April	1990	307	Yakima R.	11	2430	4	9,720

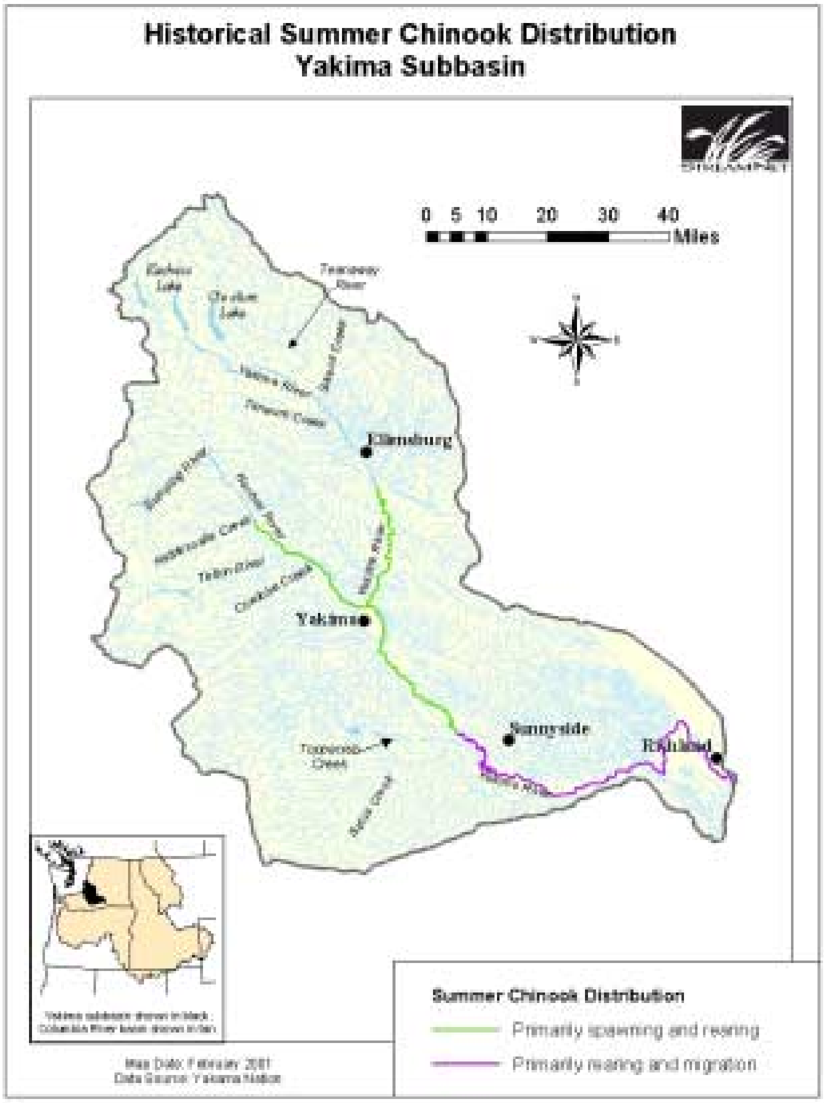


Figure 78. Historical summer chinook distribution in the Yakima subbasin

Summer Chinook *(Oncorhynchus tshawytscha)*

The Yakima River continued to support endemic summer chinook until the early 1970's. A total of three summer chinook redds were counted in the Yakima River between the confluence of the Naches River and Ahtanum Cr. in 1970 (Anon 1990), the last year summer chinook redd surveys were conducted. Prior to the 1970's summer chinook spawned in the Yakima mainstem from approximately Marion Drain to Roza Dam, and in the lower Naches from its mouth to the Tieton confluence (RM 17.5). Kreeger and McNeil (1993) and Yakama Subbasin Plan (1990) estimate historical abundance at 86,000 and 100,000, respectively. Figure 78 indicates the historical distribution of summer chinook in the Yakima basin.

Current Artificial Production - Resident

WDFW currently operates Naches Hatchery and a satellite facility at Nelson Spring. Fish are also currently raised for stocking in the Yakima subbasin at Goldendale, Mossyrock, Spokane, and Chelan hatcheries, and rarely at other facilities.

A summary of Yakima subbasin resident fish stocking summary for 1990-1000 is presented in Tables 42-45. Catchable/legal trout are10 fish per pound and larger. Fry are trout smaller than 10 fish per pound. Trout include rainbow, westslope cutthroat, eastern brook, brown, golden and kokanee. Warmwater fish include largemouth bass, black crappie, channel catfish, bluegill, and walleye.

Table 42 1990-2000 catchable/legal trout plants (numbers of fish) in Yakima subbasin

Year	Catchable trout planted in **lakes**	Catchable trout planted in **streams**	Catchable trout planted **total**
1990	209,543	29,027	238,570
1991	195,918	30,904	226,822
1992	238,284	33,913	272,197
1994	150,027*	9,292*	159,499*
1995	253,062	4,175	257,237
1996	272,426	5,069**	277,495
1997	258,609	7,059**	265,668**
1998	265082	3,577**	268,659**
1999	234,824	500**	235,324**
2000			

*Merger of WDW and WDF to form WDFW resulted in incomplete data set for 1994 that has not been finalized. The data is incomplete. True number of fish stocked are likely similar to 1993 and 1995.
**Does not include approximately 3,800 catchable rainbow trout stocked annually in Mercer and Wilson Creek by the Ellensburg Kiwanis Club

Table 43 1990-2000 trout fry plants (numbers of fish) in Yakima subbasin

Year	Trout fry planted in **lakes**	Trout fry planted in **streams**	Trout fry planted **total**
1990	558,352	58,867	617,219
1991	443,527	10,095	453,622
1992	618,548	9,220	627,768
1993	640,973	7,022	647,995
1994	61,592*	0*	61,592*
1995	536,034	2,000	538,034
1996	533,236	318	533,554
1997	863,313	0	863,313
1998	1,247,406	0	1,247,406
1999	575,958	0	575,958
2000			

*Merger of WDW and WDF to form WDFW resulted in incomplete data set for 1994 that has not been finalized. The data is incomplete. True number of fish stocked are likely similar to 1993 and 1995.

Table 44. 1990-2000 warmwater fish plants in the Yakima subbasin

Year	**Warmwater fish plants**
1990	0
1991	0
1992	0
1993	2,420
1994	8,630
1995	0
1996	5,860
1997	10,780
1998	21,845
1999	31,975
2000	

Table 45. Number by species of fish planted 1990-2000 in the Yakima Subbasin.

Species	1990	1991	1992	1993	1994*	1995	1996**	1997**	1998**	1999**	2000*
BC									15,295	31,975	563
BG								2,080			
BT	74,827	60,350	58,185	67,069	46,869	55,530	42,136	39,807	43,527	41,972	30,722
CC				2,420	8,630		5,860		5,497		
EB	27,358	22,329	18,872	27,659	1,240	13,916	10,332	7,088	3,793	3,558	3,635
GT	335	200	748	115		60		200		1,500	110
K		142,800	144,892	214,584		142,003	35,700	235,816	871,221	297,177	861,192
LMB								8,700			
RB	662,832	411,846	637,495	515,105	164,121	564,156	634,346	578,526	431,761	306,777	318,588
RxG					338						
WAL									1,053		
WCT	90,437	42,919	10,583	93,240	11,810	19,606	88,217	268,076	166,777	160,298	418,482
Totals	855,789	680,444	870,775	920,580	232,670	793,271	816,591	1,140,293	1,538,924	843,257	1,633,292

Species cods: BC = black crappie, BC = bluegill, BT = brown trout, CC = channel catfish, EB = eastern brook trout, GT = golden trout, K-kokanee,
LMB = largemouth bass, RB = rainbow trout, RxG = rainbow golden trout hybrid, WAL = walleye, WCT = westslope cutthroat trout.
* Data is incomplete
** Does not include approximately 3,800 catchable rainbow trout planted in Mercer and Wilson Creeks by the Ellensburg Kiwanis

Fish released during the past 10 years in Yakima subbasin waters include rainbow trout, steelhead trout, cutthroat trout, brook trout, brown trout, kokanee, golden trout, black crappie, walleye, channel catfish, and bluegill sunfish. Catchable trout (fish 10 per pound and larger) are planted in approximately 42 lowland lakes annually. These fish are generally 2 to 5 fish per pound, and include broodstock to 10 pounds. Fry" are fish smaller than 10 fish per pound, and range from 30 to 800 fish per pound. Fry are generally stocked in lakes and reservoirs, including high lakes. Kokanee and trout planted in high mountain or alpine lakes are generally the smallest trout planted, and are normally smaller than 500 fish per pound. Approximately 25-30 lowland and 35-45 alpine lakes are planted annually with fry.

From 35,000-871,000 kokanee fry are released annually into Cle Elum, Kachess, Keechelus, and Rimrock Reservoirs, but each reservoir is not stocked annually.

In recent years, a few lakes and ponds have been stocked with a variety of warm water fish species. Some of those fish were imported from out of state, and some were raised at the WDFW warm water fish hatchery located at Ringold on the Columbia River.

The trout released in the Yakima subbasin the past few decades are generally produced from WDFW broodstocks. Crawford (1979) described the origin and history of WDFW trout broodstocks. Rainbow trout planted in the subbasin are predominately Goldendale stock, but over the years South Tacoma and Spokane rainbow were also released in Yakima tributaries. All current and likely most past hatchery rainbow stocks have been released in the Yakima subbasin.

Westslope cutthroat originate from wild fish at Twin Lakes, Chelan County. Brown and brook trout are produced from Ford Hatchery broodstock. Kokanee originate from eggs taken at Lake Whatcom, near Bellingham, Washington.

Only Mercer and Wilson creeks within the City of Ellensburg, Widehollow Creek, and the Tieton River have been stocked with rainbow in recent years. The current Mercer and Wilson creek plants are a cooperative project to produce kids fishing opportunity with the Ellensburg Kiwanis club. WDFW will discontinue planting rainbow trout in the Tieton in 2001.

Existing and Past Efforts

Habitat

Yakima River Basin Water Enhancement Program (YRBWEP)

The Yakima River Basin Water Enhancement Program, authorized in 1994, is a multi-faceted program intended to, in part, demonstrate water conservation techniques and enhance the fishery of the Yakima River basin by working with State and Federal natural resource agencies and other interested groups. The Washington Department of Ecology is assisting with funding the four phases of the Basin Conservation Program. Other partners include the Yakama Nation, Bonneville Power Administration, Natural Resources Conservation Service and others. The irrigation districts have been primary participants in nearly all of the activities.

As directed by program legislation, water was leased from willing landowners in the tributaries to the Yakima River to improve instream flows. The leasing of irrigation water permits additional flows to be available during periods of naturally low flows in the Teanaway River and Big Creek tributary basins, thus improving conditions for the survival of anadromous fish.

YRBWEP: Kennewick Pump Exchange

Public Law 106-372, Kennewick Irrigation District Pump Exchange, was signed by the President in November 2000. This law provides authorization to study the feasibility of moving the intake system for Kennewick Irrigation District from the Yakima River to the Columbia River. The study will be closely coordinated with BPA. The project would allow irrigation flows that are currently pumped by the Chandler Pumping Plant to remain in the Yakima River for an additional 50 miles to the confluence with the Columbia River. Exchange water would be pumped from the Columbia River through a piped system for distribution on district lands. This project would improve instream flows and reduce diversions at Prosser Dam during critical fish migration and rearing periods. This option will provide, on peak average, an estimated 450 cfs of increased flow in the Prosser to Chandler reach and up to about 230 cfs of increased flow from Chandler to the mouth of the Yakima

River. Reclamation has approached the Power Planning Council for possible funding of the energy component of the Exchange under the Fish Cap.

YRBWEP: Wapatox

The Bureau of Reclamation is negotiating with involved parties to buy out the Wapatox Power Plant to benefit salmon and steelhead by increasing instream flows in the Naches River. The braided channels of the Naches River through the Wapatox Reach (river miles 17.1- 9.7) are substantially dewatered at flows of 125 cfs and below. Higher flows in the Wapatox Reach are necessary to maintain the high quality rearing habitat for steelhead and salmon and to support the food organisms that sustain those fish. Reclamation has approached the Power Planning Council for cost-share assistance on this project, and has recently submitted an application under the accelerated projects pathway.

YRBWEP: Teanaway

The Bonneville Power Administration (BPA), Bureau of Reclamation (BOR), and the Yakama Indian Nation (YIN) installed a pumping plant and pipeline in two different locations along the Teanaway River within Kittitas County near Cle Elum, Washington. This effort included the conversion of a series of three diversions and associated open earthen ditches and laterals to modern pump and pipeline irrigation systems. Two of the three systems are now upgraded to highly efficient, fully pressurized, sprinkler irrigation systems. The third system has been upgraded to a pump and pipeline delivering water to a high point on the property into a gravity-flow irrigation system. The water conserved as a result of these three water conservation systems has been transferred from its original irrigation use to instream flow use. In addition, the points of diversion were re-located to downstream pump sites, allowing all of the water to remain in the Teanaway River for an additional three miles. Funding for these water conservation systems has been provided by the Northwest Power Planning Council's Fish and Wildlife Program, which is funded by the Bonneville Power Administration (BPA). Reclamation’s Yakima River Basin Water Enhancement Program leased water for instream flow purposes in the Teanaway during the planning and construction phases.

The primary objective of this project is to increase instream flows in the Teanaway River and increase salmon and steelhead production in the stream. Improved instream flows in the Teanaway River would increase both juvenile rearing habitat and improves passage conditions for adult salmon. In addition, improved summer instream flows have been recognized as a serious problem with respect to salmon and steelhead production in the Teanaway River for many years.

Other YRBWEP Activities

The Yakima River Basin Water Conservation Program authorized by the 1994 YRBWEP Act may ultimately result in the expenditure of over $100 million on water conservation planning, feasibility investigations, and implementation of water conservation measures throughout the Yakima River Basin. Reclamation and Ecology are partners in implementing the Basin Conservation Plan with the guidance of an advisory group. Reducing irrigation district diversions and reducing district return flows is expected to improve water quality.

The YRBWEP Basin Conservation Program authorizes the expenditure of $10 million for water and land acquisition, from willing sellers or lessors, which will immediately improve instream flow conditions for fish and wildlife.

Reclamation is working with the Yakama Nation and the Bureau of Indian Affairs on the several projects authorized by the 1994 YRBWEP Act on the Yakama Indian Reservation. These include the Wapato Irrigation Project improvements and the Toppenish Creek Corridor Enhancement Project. Scientific studies and planning efforts funded under

YRBWEP are discussed later in the research and planning section of “Existing and Past Efforts.”

Yakama Nation Wetland and Riparian Restoration Project

This project has been designed to restore wetlands and riparian habitats along anadromous fish-bearing streams on the Yakama Indian Reservation. Overall goals include the protection, restoration and management of 27,000 acres of floodplain lands along the Yakima River, Satus and Toppenish Creeks (Figure 79). Direct mitigation is being realized for losses identified in the 1994 Columbia Basin Fish and Wildlife Program relating to the construction of the lower 4 Columbia River Dams. Partnership and cost-share components provided extensive project savings.

Land securing methods include purchase, easement, or long-term lease depending on the nature of the land ownership and the cost-effectiveness of the activity. About 2,000 - 3,000 acres have been secured each year since project implementation in 1995. Restoration activities seek to restore historic conditions. Land disturbing activities are subject to cultural and archaeological surveys, and are used only on properties that have suffered past disturbances. Native vegetation re-establishment, and a return to some semblance of historic hydrology are the goals on the restoration sites. Restoration efforts are designed to be as self-sustaining as possible to minimize operations and maintenance costs needed to preserve habitat values.

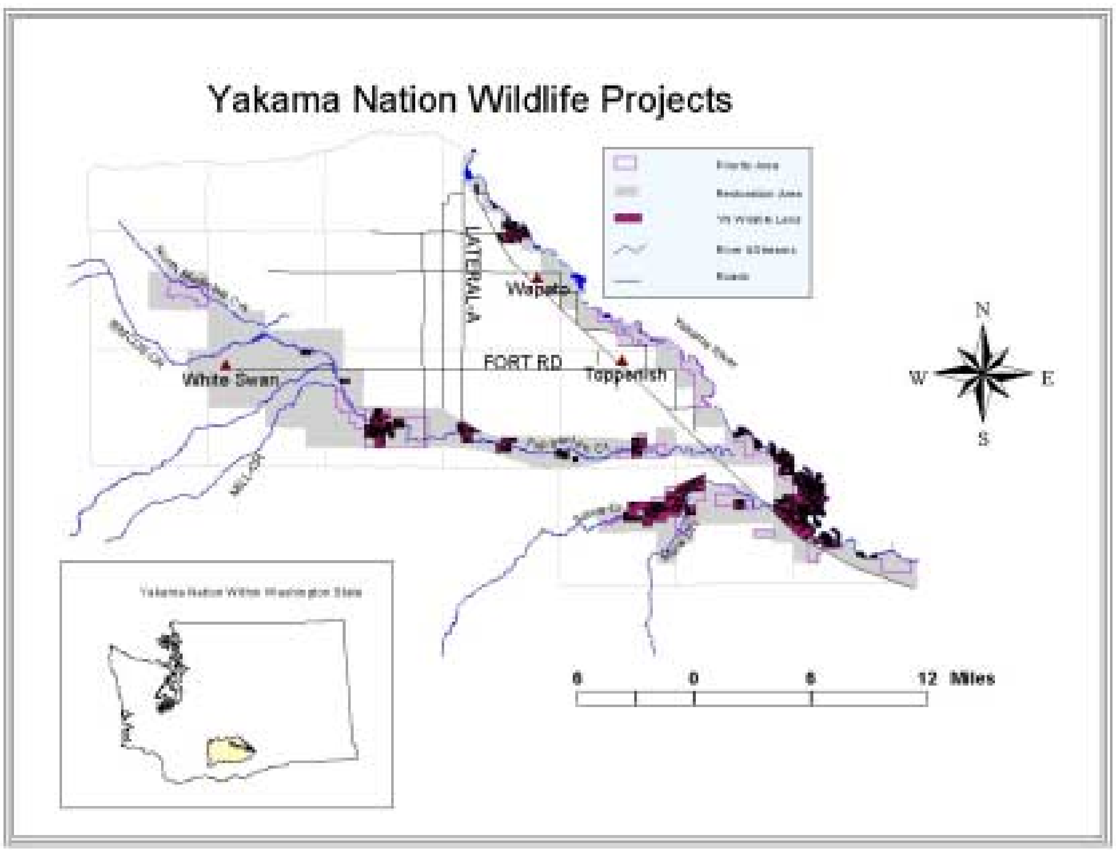


Figure 79. Yakama Nation wildlife projects

The expected outcomes of the project are native riparian and wetland floodplain complexes along the anadromous fish-bearing streams on the Yakama Indian Reservation. Results are monitored using HEP. Specific vegetational, population and hydrologic results are also monitored at each property to ensure that restoration goals are being met in a cost-effective manner.

Priority Area 1 - South Lateral A

This 430 acre property is located along Toppenish Creek. It originally consisted of creek floodplain habitats including emergent marsh, and three channels of the braided Toppenish Creek. Past agricultural development had removed this property from the floodplain, drained the wetlands, and totally removed the north channel of Toppenish Creek. The property was secured into the Project in 1994. Restoration designs were developed soon after and implementation of restoration activity occurred in the fall of 1995. Restoration included the reestablishment of the north channel of the creek, development of emergent marsh habitat associated with the north channel, and the restoration of floodplain grasslands. Record flooding in early 1996 damaged some of the restoration work. In light of this flood damage, a spillway system was designed and installed in 1996. Funds from FEMA were used to install the spillways. Another large flood again occurred in January of 1997. Because of the spillway design only minor damage occurred. The return of historic hydrologic conditions and native vegetation has resulted in an immediate wildlife response. Waterfowl production was measured in the spring of 1997. The surveys (Table 46) indicated some of the densest production recorded in the valley. Summer waterfowl banding activities captured over 400 mallards on the property in July and August. Other species of note that have been extensively using the property for nesting include long-billed curlews, and black-necked stilt. Sandhill cranes, peregrine falcons and bobolinks have also been observed on the property during the nesting season. Great basin wild rye plantings on over 150 acres of the property provide nesting cover for many species of wildlife.

Table 46. Annual wildlife surveys in the Yakima Subbasin.

Survey	Dates	Agency or Tribe
Canada Goose Nesting	April 7 – April 15	WDFW, YN
Duck Pair Counts	May 10 – May 25	WDFW, YN
Duck Brood Counts	July 1 – July 10	WDFW, YN
Summer Duck Banding	July - August	WDFW, YN, USFWS
Wintering Waterfowl Counts	Oct. – March	WDFW, YN, USFWS
Mourning Dove	May 20 – May 31	WDFW, YN
Sage Grouse Lek Counts and Surveys	February – April	YTC
Upland Gamebird Brood Counts	July – August	WDFW, YN
Bald and Golden Eagle Occupancy	March - April	WDFW, YTC, YN
Bald and Golden Eagle Production	Late June	WDFW, YTC, YN
Ferruginous Hawk Occupancy[1]	May 1 – May 10	WDFW, YTC
Ferruginous Hawk Production[1]	July	WDFW, YTC
Burrowing Owl Nesting[1]	April – July	WDFW, YTC
Prairie Falcon Occupancy[1]	March-April	YTC
Prairie Falcon Production[1]	May-July	YTC
Jackrabbit	Aug. – Sept.	WDFW
Big Horn Sheep	June	WDFW
Big Horn Sheep	Jan. – Feb.	WDFW
Elk	Sept. 16 – Sept. 31	WDFW
Elk	Feb. – March	WDFW, YN
Deer	December	WDFW, YTC
Passerines[1]	May	YTC
Bald Eagle Roost Counts	Dec.-March	YTC
Bald Eagle Columbia R. Day use	Dec.-March	YTC

Spotted Owl Nest Monitoring	Mar-Sept	USFS, YN

[1]On YTC passerines are surveyed for 3 years then raptors are surveyed for the next 3 years. Bald eagles, however, are surveyed every year.

Priority Areas 2, 5, and 10 - Satus Wildlife Area

This property, located at the confluence of Satus Creek and the Yakima River, is comprised of nearly 6,000 acres. Unlike the South Lateral A property which had been heavily disturbed in the past, the Satus Wildlife Area's landscape has been relatively unaltered from native conditions. The property represents some of the highest quality oxbow slough wetland and gallery riparian forest habitats on the Yakima River. Historical land use was limited to intensive cattle grazing. The property was secured in 1995. The site-specific management plan reduced the cattle allotment by 75%, and incorporated cattle into a rotational system designed to aid restoration. Wetland restoration planning occurred in FY98. Restoration consisted of water control structure replacement, not landscape alteration. Wetland restoration activities were funded through NAWCA with some FEMA funds used for spillway design and installation. Vegetation restoration and replanting began in 1997, and is ongoing. Broad, flat meander-belt areas such as this are nearly nonexistent along the Yakima River. This property is among the best examples of this landscape type in central Washington. The wildlife diversity is equally represented on the property.

Priority Area 3 - Wapato Wildlife Area

This property, located along the Yakima River north of the city of Wapato, is comprised of 660 acres of braided Yakima River habitat, gallery cottonwood forest, and grassland areas, which had been converted to agriculture in the early part of the century. Restoration of this property is complete as of 1997. Most of the restoration consisted of reestablishing great basin wild rye grasslands and natural hydrology on the converted farmland (~160 acres). The riparian areas have been protected from grazing and are relatively undisturbed. Hydrologic restoration of the converted agricultural areas has resulted in young cottonwood and willow re-colonization. Spawning coho salmon have been documented on the property since 1999.

Priority Area 4 - Lower Satus Creek

The Lower Satus Creek unit consists of approximately 2,500 acres of floodplain habitat in the west portion of the Satus Valley. This portion of Satus Creek was once comprised of a multiple-channeled riparian/wetland complex. Past activities have resulted in channel simplification in this area. Today only one channel remains; down cut through years of abuse. Restoration of channel complexity can be accomplished through reconnection of the old channels as many of the landscape features remain. This property also provides the link between this Project and the Satus Creek Watershed Project being implemented throughout the non-agricultural portion of the Satus Creek watershed.

Priority Area 11 – Mouth of Wanity Slough

This property consists of 400 acres of wetland habitat along Toppenish Creek. This location is the historic confluence of Wanity Slough, cut off from Toppenish Creek during the irrigation development of the area in the early part of the century. The hydrology of Wanity slough was reconnected through the installation of a solar pump station.

Priority Areas 12 and 15

This 1,400-acre property consists of a large wetlands complex amid a multi-channeled portion of Toppenish Creek. Restoration efforts are targeting wetland hydrology, native grasslands, and Russian olive removal. NAWCA funding was used in FY99 to begin the wetlands restoration component of this property. Further restoration activities are planned over the next several years.

Cowiche Creek Riparian Restoration

The Cowiche Creek Riparian Restoration project was implemented in 1994-96 with funding under section 319 of the Clean Water Act. The project reached nearly all private landowners in the project area, which included the agricultural area of the Cowiche Creek watershed. A total of 15 restoration projects were implemented. Water quality monitoring was conducted, and education extended to the public classroom, where presentations were given on fish habitat and water quality to schoolchildren. Presentations were also given at Yakima's annual Earth Day celebration in 1994, 1995 and 1996 which was attended by over 1500 area residents. Funding for project implementation was also gained from the US Fish and Wildlife Service, and the USDA.

Wilson Creek Riparian Restoration

The Wilson Creek Riparian Restoration project, which is similar to the Cowiche Creek project, was funded by BPA and the eastern Washington Regional Fisheries Enhancement Group. Over 30 landowners were contacted in 1996-1998, and 15 projects were implemented, resulting in the construction of almost three miles of livestock fencing and the planting of 10,000 riparian plants. Classrooms were involved in restoration, and presentations were given to local groups such as the Rotary, Audubon, local City Council and the larger community.

Dixon Project

The Dixon protection project involved purchase of 31 acres of prime floodplain/side channel habitat in the Cle Elum Reach of the Yakima mainstem, with funding from Bonneville Power Administration. A mile side channel flows through the property, which also includes a large island and 2500 feet of shoreline along the river. Purchased in 2000, this acquisition helps protect rearing productivity in the Cle Elum reach.

Foster Protection and Restoration Project

The Foster protection/restoration project involved purchase of 59 acres of floodplain habitat on the lower Naches River, with funding from the eastern Washington Regional Fisheries Enhancement Group and Bonneville Power Administration. During the 1996 flood this reach of the river cut a new channel across state and private land. Adjacent private landowners desired to straighten the river and move it to an old location, thereby eliminating newly created, productive rearing habitat. Through negotiations with landowners, the restoration project was implemented in a manner that addressed landowner's concerns about future flooding. In addition to purchasing private property that abuts WDFW property, two small setback levees were constructed with a 50/50 match from the landowners, to protect residences.

Henne Protection Project

The Henne protection project involved purchase of 137 acres of prime floodplain habitat on the Yakima River, near Union Gap, in 2000, with funding from the eastern Washington Regional Fisheries Enhancement Group, and Bonneville Power Administration. This property contains numerous backwater alcoves and wetlands. Riparian habitat that is already properly functioning in many locations is expected to improve through this effort.

Brunson Riparian Restoration and Protection

The Brunson riparian restoration/protection project involved phased construction of 5200 feet of livestock fence along the mainstem Yakima and two small tributaries. The work began in 1994, with the last phase completed in 1998, with funding from Washington Department of Natural Resources and the eastern Washington Regional Fisheries Enhancement Group. Livestock grazing in the riparian area was thus eliminated. In total, 850 riparian plants were sown. Riparian productivity will be restored through this effort.

Teanaway Junction Boat Ramp

The Teanaway junction boat ramp project involved placing boulder clusters and large woody debris (large woody debris) along 100 yards of simplified side channel habitat, to enhance habitat complexity, ultimately improving juvenile rearing habitat. The project was implemented in 1997, with funding from the eastern Washington Regional Fisheries Enhancement Group. The project manager anticipates placing additional large woody debris in the project in next year.

Lower Naches River

An intensive protection effort has begun in the lower Naches River. A public outreach effort was implemented in 2000, and as a result 12 landowners have expressed interest in selling their property. Some of the affected parcels are contiguous. With continued emphasis managers expect the project to continue building momentum, eventually protecting a large number of parcels in this reach. Funding is expected to come from several sources, including Bonneville Power Administration, the Salmon Recovery Funding Board, the eastern Washington Regional Fisheries Enhancement Group, and other sources.

Toppenish-Simcoe Instream Flow Restoration and Assessment

Although relatively small, Toppenish Creek drainage contributes 20% of the Yakima's summer steelhead run, a threatened stock under the Endangered Species Act. The Toppenish Simcoe-Unit of the Wapato Irrigation Project diverts streamflow from Toppenish Creek and its tributaries, often desiccating long reaches of streams and killing juvenile steelhead. The project's purpose is to restore instream flows to Toppenish Creek and to modify irrigation diversions to mimic natural runoff so that favorable, year-round conditions exist for all life stages of steelhead and other aquatic species. Instream flow restoration will occur through leases or purchases of land with water that can be returned to streams and/or thorough water substitution. If land acquisition is not possible, the project will work with landowners to restrict diversion to periods when surface discharge is not limiting (e.g., spring runoff). This BPA-funded project began in 1998 with the collection of baseline data, water budget modeling and management planning. Plan implementation will begin in 2001. To measure biological outcomes, the project uses yearly screw trap outmigrant data, spawner survey counts, electrofishing and snorkel survey data to provide indices of steelhead abundance. Discharge and groundwater monitoring data will help assess the effect of streamflow restoration on creek and floodplain. Also, DNA samples from steelhead smolts will be evaluated to determine genetic similarity to other Yakima basin steelhead stocks.

Satus Watershed Restoration

The Satus Watershed Project, initiated in 1996 with BPA funding, was conceived as a long-term, large-scale restoration and monitoring effort designed to develop, apply, and evaluate cost-effective methods for restoring fish habitat. The project's objective is to enhance and protect summer steelhead spawning and rearing habitat by restoring the ecological functioning to the Satus Creek watershed. In recent years Satus Creek, which is entirely within the Yakama Reservation, accounts for more than 1/3 of the Yakima subbasin's returning adult steelhead. Restoration activities will also favor riparian-dependent wildlife species and reestablishment of coho and spring chinook. The project continues the landscape-scale restoration and monitoring undertaken by the Yakama Nation Satus Watershed Project. Several major complementary projects, funded by six state and federal agencies, are also underway within the watershed. An extensive monitoring system is in place, quantifying the value of coordinated watershed-scale restoration.

Habitat restoration is intended to reduce erosion, increase channel/floodplain interactions, increase sediment trapping and improve vigor of riparian vegetative communities (Brooks et al., 1991; FWP 1995). The goal is recovery of the water storage and retention characteristics of the watershed and reestablishment of runoff characteristics closer to the historical norm.

Past accomplishments include the establishment of both streamflow and climate monitoring networks; improved grazing management including enforcement of permit compliance; reestablishment of native vegetation; headwater meadow restoration which involved stabilizing incised channels and increasing sediment trapping; placement of large woody debris; planting of aspen trees on sites suitable for beaver habitat; beaver reintroductions; dike removal; mapping of Satus Creek riparian vegetation and stream channel for the years 1949, 1995 and 1997; and road relocation/obliteration including along four miles of floodplain.

To measure biological outcomes, the project conducts habitat unit surveys; annual redd counts; smolt trapping; stream gauging, and Proper Functioning Condition assessments; and has gathered electrofishing data from representative stream reaches. The data are available on the Yakima-Klickitat Fisheries Project web site.

Ahtanum Creek Watershed Assessment

Ahtanum Creek and its southernmost tributaries form part of the north boundary of the Yakama Indian Reservation. This watershed was historically important for production of salmon, steelhead and bull trout. Today spring chinook and coho are found in small numbers, while two threatened species, steelhead and bull trout are even fewer. The purpose of the project is to conduct a watershed assessment of Ahtanum Creek, particularly the lower, largely agricultural portion of the creek where water withdrawal, diking, channelization, grazing and residential development adversely affect the floodplain. The assessment will facilitate science-based strategies to restore streamflow to reaches of Ahtanum Creek that dewater annually and thus provide favorable, year-round conditions for all life stages of steelhead, coho, bull trout and other aquatic species. Inaugurated in May 1999, the project has mapped irrigated lands and water delivery systems, measured water discharge and temperature, compared water diversion and loss with on-farm water needs, and estimated the efficiency of irrigation water conveyance and use. The project has also gathered historic and current data on stream channel condition, riparian function and salmonid populations; analyzed this data to determine how water use and riparian management in lower Ahtanum Creek may be limiting production of anadromous salmonids in the watershed as a whole, and have begun to determine the most effective measures for fish restoration. After completing data analyses and the Project Assessment Report, the project will recommend restoration measures in 2001 that could include improved irrigation facilities, land and water management changes, and purchase or lease of land and water rights.

Upper Toppenish Creek Watershed Restoration

This project addresses degradation in the upper Toppenish Creek watershed, complementing three major restoration efforts underway in the lower, agricultural portion of Toppenish Creek. Restoration of the Toppenish watershed is critical to restoring healthy runs of threatened Yakima River steelhead. The purpose is to improve steelhead habitat by moderating flows from the upper watershed by restoring soil water retentiveness in areas such as headwater meadows and floodplains. The measurable biological objectives are to reduce erosion, aggrade downcut channels, and restore channel/floodplain interactions. Following a plan generated by a 1998-99 hydrologic assessment, this BPA-funded project will employ methods that include improving grazing management; stabilizing headcuts and constructing sediment traps in headwater areas using native materials and geotextiles;

revegetating sediment deposits and eroding uplands; and enhancing stream/floodplain interaction.

Hanson Ponds Floodplain Restoration Project

A reach along the mainstem Yakima has multiple large parcels with tremendous restoration potential. The project would also provide flood protection, as the relocation of a Corps of Engineers PL 84-99 levee that lies immediately adjacent to the channel could be setback from the river a considerable distance. The levee has suffered repeated damage during flood events, and it protects mostly open rangeland. This would provide more assurances that the levee would remain intact during a large flood. The results would be greater floodplain connectivity, with much improved watershed conditions for anadromous fish.

The Hanson Ponds Floodplain Restoration Project will add one mile of side channel habitat, improve floodplain connectivity, restore riparian habitat adjacent to the river, improve channel complexity, and increase recreational opportunities. The project involves removing portions of an armored levee that is .9 miles in length, and allowing a portion of the Yakima River to flow through the ponds. The levee surface will be reworked to allow riparian vegetation to reestablish. Large woody debris will be incorporated into the shallow ponds that will provide refuge habitat for juvenile salmon, resident trout and steelhead. Roughly 60 % of the Yakima Basin spring chinook spawn upstream of the project area. The project is in a “cold water” reach, where competition and predation from non-native piscivores is not considered a significant problem. The project is a collaborative effort involving the City of Cle Elum, Yakama Nation, and the Washington Departments of Transportation, Natural Resources and Fish and Wildlife. Funding is proposed as a cost-share between National Marine Fisheries Service, Washington State Department of Natural Resources, Washington Department of Transportation, and Bonneville Power Administration.

Taylor Ditch Assessment/Restoration Design

Taylor Ditch is a modified side channel of the mainstem Yakima that holds great restoration opportunity. Funding was secured from the Governor’s Salmon Recovery Office to do a public outreach effort, and assess water quality and habitat function of the system. A suite of restoration actions is being developed from the assessment, which is expected to be completed by the end of spring 2001. Restoration actions will be implemented under the next phase of the project, once funding is secured.

Buckskin Slough Assessment/Restoration Project

This project is being implemented under two phases. In phase one, water quality data was gathered, and affected landowners were contacted to discuss habitat issues. One large “town hall” meeting was held in the area. A suite of restoration prescriptions was developed for individual properties. Participation has been excellent, with approximately 70% of the contacted landowners volunteering to have a restoration project implemented on their property. Phase two will be implemented spring 2001. During the second phase all restoration projects will be implemented, within available funding. WDFW activities planned for phase two include planting native vegetation, placing in-stream structures, constructing livestock exclusion fencing and conducting reed canary grass control.

Wenas Creek Restoration Project

The Washington Salmon Recovery Funding Board approved funding in January 2001 for a North Yakima Conservation District project to restore fish habitat in the lower end of Wenas Creek, three miles north of Selah by replanting creek bank vegetation and placing large woody debris in the creek. Students from the Selah School District will also monitor water quality and quantity as it relates to possible salmon and steelhead recovery needs.

Yakima River (Near Selah) Bank Stabilization Project

A joint project of the North Yakima Conservation District, Washington Fish and Wildlife Department and Tree Top Inc will stabilize the Yakima River bank south of the Harrison Road Bridge, east of Selah. The project is designed to end erosion along the border of the apple processor's spray field adjoining the river, as well as increasing flood plain accessibility through removal of an existing dike. In addition to funding from the Washington Salmon Recovery Funding Board, Tree Top is providing staff and equipment required for the project.

Yakima County Department of Corrections Replanting Project

Using funding received from the Salmon Recovery Funding Board, the Yakima County Department of Corrections will be using inmate work crews to replant native vegetation and remove exotic weeds on public and private property along streams.

Woody Debris Placement

The Washington Department of Fish and Wildlife will be placing woody debris in the Yakima and Naches rivers using funds received from the Washington Salmon Recovery Funding Board in January 2001.

Olin Nichols Teanaway Riparian Planting

Funding has been secured for a WDFW project to plant native vegetation along the Teanaway River.

Stovall Property Restoration

Planting of native vegetation and placement of in-stream structures in Taneum Creek will occur during the summer 2001. This WDFW project is funding by.

Plants for Stream Restoration

Additional funds were secured by WDFW to help establish a native plant nursery in Kittitas County.

Sevin-Rouleau Stream Bank Restoration

A WDFW-managed project planted native vegetation and bank barbs along the Yakima River near Cle Elum.

Fritorito Ponds

A WDFW project of re-vegetation and root wad placement in Fritorito ponds has been completed.

Liddington Bank Stablization

A WDFW project to plant vegetation along a stretch of the Yakima River for bank stabilization will take place in spring 2001.

Cowiche Canyon Conservancy Re-vegetation

The native plantings of phase one of this WDFW project will be continued in phase two. Phase two will also include connection of isolated side channels.

Buckskin Slough Spawning Gravels

WDFW placed ten cement mixer loads of spawning gravel in Buckskin Slough.

Shaw Creek Re-Vegetation

WDFW has received funding to replant native vegetation along Shaw Creek, a tributary of Wide Hollow Creek. This is part of a larger project.

West Valley Park

Funded by the Salmon Recovery Funding Board, this on-going WDFW project includes extensive plantings, grade controls and removal of a berm along Wide Hollow Creek.

WDFW also partners in a West Valley Park expansion/Wide Hollow Creek restoration project with Yakima park officials and planners, North Yakima Conservation District and West Valley teachers and students, through the Bureau of Reclamation and Wapato School District environmental education teacher training program. Esbach Park
Native vegetation planting has been completed and in-stream structures are being place in a tributary of the Naches River through this WDFW project funded by the Aquatic Lands Enhancement Account.

Yakima Basin Environmental Education Training Program Habitat Projects

A number of past and on-going restoration projects have been developed through teacher and students involvement in the Bonneville Power administration's Yakima Basin Environmental Education Teacher Training Program, in cooperation with the Bureau of Reclamation. Some of these projects are described below. Additional projects include: Central Pre-mix, Airport, Randall Park, Edler Ponds and Selah Ponds projects.

Selah Ditch Improvement Project

This project involves Selah Middle School in the improvement of the ditch to provide fish habitat for wintering. Students monitored the area both before and after the improvements were made, planted trees and shrubs, and will continue to monitor water quality and habitat. Partners include Bureau of Reclamation, BPA, Washington Dept. of Transportation, North Yakima Conservation District, EPA, Watershed Stewards Program, City of Selah, Yakama Indian Fisheries.

Harrison Road Project

This project will begin this year and involve students from the Selah School District in the rehabilitation of this area along the Yakima River. The area will provide opportunities for water quality monitoring, riparian restoration, and enhancement of habitat for fish and wildlife. The area has been used as a bird rookery and will provide students with unusual opportunities of enhancement of bird habitat. Partners include Bureau of Reclamation, BPA, North Yakima Conservation District, Audubon Society, and Watershed Council.

Kern Road Restoration Project

North Yakima Conservation District supplies native plants for this BOR/Wapato School District wildlife restoration project along the canal walkway.

Wide Hollow Creek/West Valley Schools

Students maintain the newly built nature trail, plant and access riparian corridor areas, do water quality testing, and litter clean up at this on-going restoration and salmon release site behind West Valley Junior High and Middle School. Three aquariums of salmon in the middle school, one aquarium in the junior high and one aquarium in Wide Hollow Elementary School are released at this site each spring. This project results in 1500 salmon fry entering the creek at this site, across from creek from the West Valley park expansion project.

Tapteal Greenway Habitat Stewardship Projects

Since 1995, the Tapteal Greenway volunteer organization have partnered with other organizations in a number of habitat improvement projects in the Tapteal Greenway area from Benton City to the mouth of the Yakima River. Projects have included:

- habitat restoration at Chamna Nature Preserve through Richland's Adopt-A-Park program;
- developing an on-going water quality monitoring program with WSU Mater Watershed Stewards and other volunteers;

- planting 8000 sagebrush tublings at Horn Rapids County Park following the Hanford fire;
- conducting on-going cleanups along the lower Yakima River, with individual and agency participation; and
- purchasing Tapteal Bend, in the lower Yakima River, for a bank stabilization demonstration as well as on-going environmental education and habitat protection and restoration. Students from St. Pauls elementary School program participate in restoration activities as part of the Bureau of Reclamation Environmental Education Training Program.

Nutrient Enhancement

WDFW has placed 1,200 the first year and 2,000 fall chinook carcass into the American, Bumping, and Little Naches each of the last two years (3 years total) for nutrient enhancement. WDFW intends to conduct this project annually.

WDFW Warmwater Gamefish Enhancement

The WDFW Warmwater Gamefish Enhancement Program has rehabilitated four lakes to remove undesirable fish populations, and have restocked these lakes with more desirable warmwater game fish species. Artificial structures have been placed in five waters to enhance warmwater fish habitat. Ongoing efforts include increasing efforts to protect Washington's freshwater ecosystem from deleterious exotic species such as zebra mussel and undesirable aquatic plants; developing new lakes and ponds for warmwater fishing; and purchasing and producing warmwater fish for stocking.

Waterfowl Restoration

Efforts to restore the waterfowl resources of the Yakima Basin are being undertaken by the Yakama Nation (Meuth 1989, Bich et al 1991), the Washington Department of Fish and Wildlife (Sunnyside Management Plan), and the U. S. Fish and Wildlife Service (Toppenish NWR Plan). The Ducks Unlimited and Pheasants Forever organizations are also active in assisting these restoration activities (Hames 1999). The Bonneville Power Administration is currently funding the management and restoration of nearly 25,000 acres of wetland and riparian habitats in the lower Yakima Subbasin (Hames 2000, Sunnyside Management Plan). By improving wintering waterfowl habitat conditions, advocates and wildlife managers expect to see wintering ducks and geese return to the lower Yakima. Ratti and Kadlec (1992) emphasized the importance of lower Yakima Subbasin to waterfowl populations of the Intermountain West. As a result, the Yakima Basin was identified as a Focus Area within the Eastern Washington portion of the Intermountain West Joint Venture of the North American Waterfowl Management Plan (LaTourrette 1996).

Wenas Wildlife Area

Several enhancement and restoration projects have been implemented over the proceeding three years to improve habitat quality for endemic wildlife species, including fenced tree and shrub plantings, pond and wetland development, and conversion of abandoned agricultural fields to native like habitat. Livestock grazing had been eliminated from lands owned and/or managed by WDFW within the Wenas Wildlife Area. Figure 80 shows the location of Wenas Wildlife Area. (Also see Wenas Wildlife Area under Protected Areas in the Subbasin Description). Table 47 indicates cover types and amounts in the Wenas. Historically, agricultural fields located on both sides of Wenas Creek were used for hay production an/or pasture for the livestock. When acquired by WDFW in the late 1960s, hay production was maintained for WDFW's winter elk feeding program. These agricultural fields were seeded to native grasses, forbs, and shrubs in late fall of 1998. Additional on-going enhancement activities include the following projects:

Roza creek Rocky Mountain Elk Foundation (RMEF) Cooperative Project

This RMEF cooperative project is designed to enhance shrub-steppe and riparian forest habitats in the Roza Creek drainage. Enhancements include controlling weeds, seeding native-like herbaceous vegetation, and planting shrubs and trees. Physical enhancements to improve stream hydrology are planned and include construction of small impoundments, restoration of creek channels, and removal of existing culverts and diversions (all required permits will be obtained before work is initiated). Drainage-wide weed control will be conducted on approximately 1,500 acres over the next five years.

Cottonwood Creek RMEF Cooperative Project

This RMEF cooperative project will restore existing weed infested grasslands to native-like shrub-steppe habitat. Planned enhancements include planting native grasses and shrubs and reducing weed competition as needed. Ultimately, restoration of the lower Cottonwood Creek drainage will encompass 1,650+ acres. Streambed restoration and limited shrub planting will continue along Cottonwood Creek after grassland restoration has been completed.

McCabe RMEF Cooperative Project

This RMEF cooperative project is designed to restore former agricultural land to native-like shrub-steppe habitat and to enhance existing riparian/wetland sites. Future work includes: controlling weeds, planting shrubs and trees, fencing woody plantings (to protect them from elk/deer depredation), and enhancing existing ponds and wetland areas.

Sheep Company Road Project:

This project is similar to other RMEF cooperative projects and includes replanting 150 acres to shrub-steppe habitat, intensive weed control on an additional 200 acres not suitable for replanting, removal of demolished farmstead buildings and debris, repair and operation of an existing well to provide short-term irrigation of new shrub and tree plantings, and construction of fence enclosures to temporarily protect shrub and tree plantings from elk depredation. Annual weed control will continue on the project until native-like vegetation replaces undesirable introduced plant species.

Road Weed Management:

There are approximately 350 miles of road on the Wenas Wildlife Area of which one half are open to public use (Green Dot Program). Both open and closed roads exhibit some degree of weed infestation. An aggressive weed control program is planned over the next five years with open roads commanding the highest priority. Weed control treatments will occur on most areas annually or until desired levels of control are achieved. WWA staff will develop a plan to control weeds on at least 50 miles of road per year.

Weed Management on Uplands, Draws, and Trails

There are localized infestations of noxious weeds, varying widely in size and density, scattered throughout the entire WWA. An aggressive 5-year weed control program is planned and will continue as long as needed. While springs and riparian draws will receive the highest priority, additional weed control measures will be required to reduce knapweed, thistle and other exotics on upland sites.

Biological Weed Control

Biological control agents will be purchased annually from Idaho State University and/or Washington State University, and will be dispersed on key sites to supplement and/or provide an alternative to herbicide applications. Once established, biological control agents will be collected from local sites and dispersed to other areas on the WWA. Biological control agents have been released on other wildlife areas in Washington and are consistent with WDFW's integrated vegetation management strategy.

Competitive Native-like Vegetation Seedings

Native-like herbaceous vegetation will be established on treated sites to compete with exotic vegetation (this should result in a reduction in the number and intensity of future herbicide applications). Generally, native seed mixtures will be applied at a rate of 10 pounds per acre unless otherwise indicated by site-specific conditions.

Riparian Forest Enhancements

The succession of various riparian tree/shrub stands will be set back by cutting or hedging trees and shrubs to stimulate new growth and increase plant vigor. These sites include locations in the Wenas and Umtanum Creek drainages, along with upland sites at Wright and Oasis Springs. Fencing of treated stands may be required to protect new growth from deer, elk and bighorn sheep depredation.

Riparian Area Development

Riparian forest/shrub habitat will be developed on a former alfalfa field at the Mt. Vale Headquarters site. Existing wells will be used to irrigate the proposed enhancement. Weed control and protective fencing are also planned. Exercising water rights for this purpose will ensure that WDFW retains its water rights to the wells (inactivity for 5 years will result in the loss of water rights).

Umtanum Ridge Access Road

This primitive road located adjacent to Umtanum Creek (a Type 3 stream) will be abandoned, seeded to native vegetation, and maintained by WDFW in order to reduce road density and eliminate a source of stream siltation. Work will include restoration of the adjacent stream channel to its historical flow pattern, removal of five existing culverts, planting and fencing of shrubs and trees along the stream, and heavy thinning of several small, decadent aspen stands. Thinned areas (generally 1-2 ac) will be temporarily fenced to prevent damage by browsing elk.

Umtanum Creek Crossing

An existing rock ford through Umtanum Creek allows considerable sediment and vehicle related pollutants into the creek. Alternatives to the existing ford are being considered to determine the most cost effective/practicable replacement option. Potential improvements include: installation of a concrete box culvert, installation of a metal culvert of sufficient size to meet flow requirements, improvement of the existing ford to allow for dry vehicle crossing during typical low flow regimes, and installation of a full bridge. Off-road vehicle access and overnight camping will be restricted to protect riparian habitat and reduce disturbance to fragile soils. Intensive weed control measures will be conducted to reduce noxious weeds on the site. Additionally, grass seeding and riparian tree enhancements will take place on disturbed riparian areas.

Hanson Road Project

A spring-fed two acre artificial impoundment (formerly used for stock watering) will be partially breached or allowed to drain to restore surface/subsurface flow to historical riparian habitat. An existing road will be closed and relocated out of the riparian zone followed by restoration of the riparian area. Temporary protective fencing will be constructed as needed to prevent degradation of shrubs and trees by elk and other wildlife species.

Skyline Trail Access Project

A high use weed infested ATV road will be abandoned and re-vegetated with native-like shrub-steppe vegetation. An existing parking lot and horse staging area at the entrance gate will be enlarged and enhanced to offset the loss of the closed road, which has traditionally been used by equestrian groups as access/parking for horse trailers.

Forest Practice Act Road Abandonment

A road management plan is being developed to identify which roads should be abandoned or repaired. All remaining roads throughout the WWA will be restored in order to reduce the spread of noxious weeds and lower stream sedimentation.

Mitigation Habitat Gains

Wenas Wildlife Area is a BPA-funded mitigation project that provides habitat for both T&E species and Priority Habitat Species (PHS). WWA is an important link in WDFW's ongoing efforts to reverse downward population trends in shrub-steppe obligate wildlife species, such as sage grouse, and to improve water quality for both anadromous and resident fish alike.

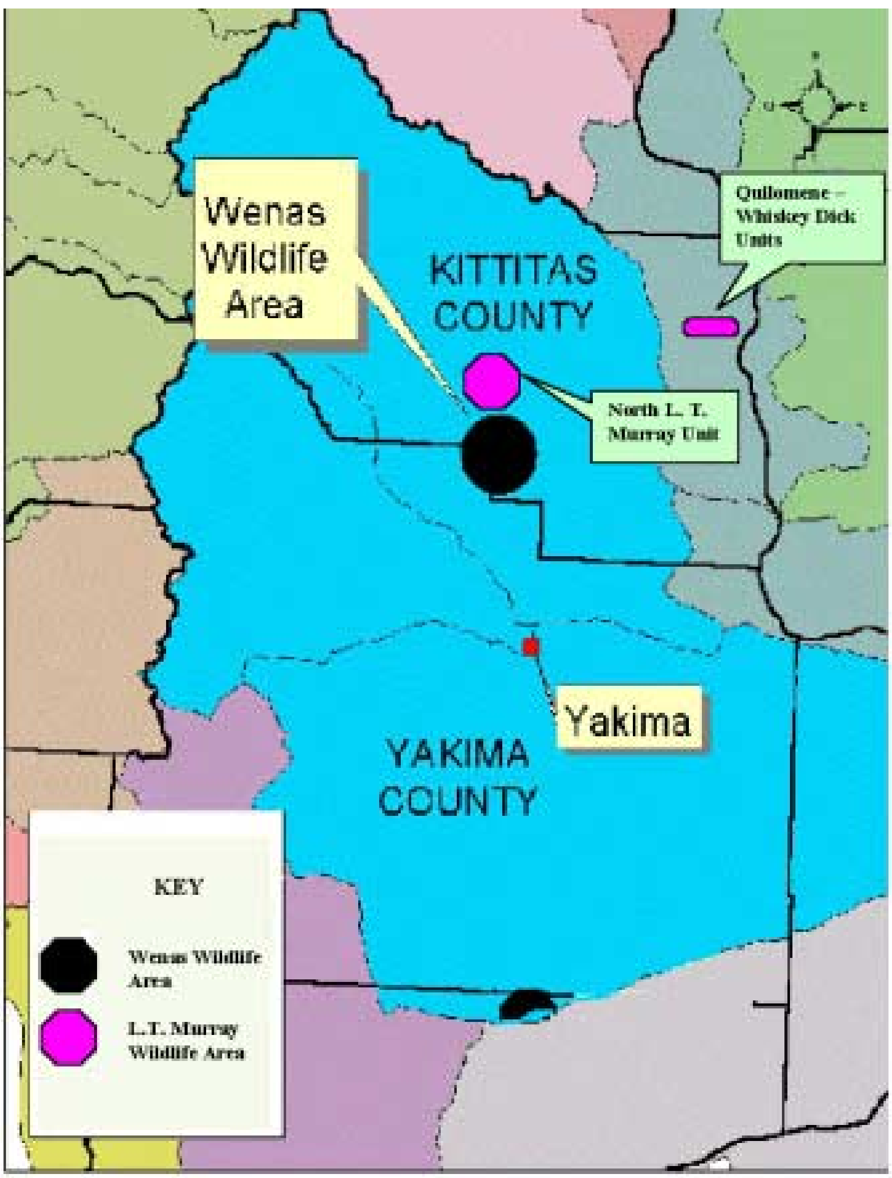


Figure 80. Wenas Wildlife Area location map.

Washington Department of Fish and Wildlife owns 28,771 hectares (71,093 acres), leases 12,401 hectares (30,643 acres) from the Department of Natural Resources, and manages 3,485 acres for the Bureau of Land Management. The WWA is divided into four management units (Unit); the 12,566 hectare (31,050 acre) North Cleman Mountain Unit, the 14,254 hectare (35,220 acre) South Umtanum Ridge Unit, the 5,201 hectare (12,852 acre) Roza Creek Unit and the 10,562 hectare (26,099 acre) Umtanum Creek Unit (WDFW 2001) (Figure 77).

Table 47. Cover amounts and baseline habitat unit summary for the WWA.

Cover Type	Hectares - Acres	Species	Habitat Units
Grassland	28,160 - 69,582	Western Meadowlark	12,240
Shrubland	7,064 - 17,455	Mule Deer	2,611
		Sage Grouse	1,623
Riparian Forest	491 - 1,213	Black-capped Chickadee	389
Riparian Shrub	153 - 379	Yellow Warbler	84
Riverine	68 - 168	Mink	17
Woodland Forest	3,991 - 9,861	Mule Deer	801
Medium Conifer Forest	1,798 - 4,443	Mule Deer	731
Dense Conifer Forest	854 - 2,110	Mule Deer	45
TOTAL	42,583 - 105,221	All Species	18,541

Sunnyside Wildlife Area

A number of mitigation-related habitat and land acquisition projects have occurred or are in progress in the Sunnyside Wildlife Area (see Protected Areas for a description of this area).

The Sunnyside Wildlife Area has been approved as a wildlife mitigation project by BPA. This project will partially meet BPA's mitigation obligation to compensate for wildlife losses resulting from the construction of Grand Coulee, McNary and John Day Dams. By funding the enhancement and reasonable operation and maintenance of the Sunnyside Wildlife Area for the life of the project, BPA will receive credit towards its mitigation debt. Mallard, Western Meadowlark, Canada Goose, Yellow Warbler, Downy Woodpecker, Mink, California Quail, Black-capped Chickadee, Great Blue Heron, Mule Deer and Sage Grouse were identified in the loss assessments and were used as HEP indicator species (Howerton 1986, BPA 1989, WDFW 1998).

Griffin Lake Watershed Restoration Project

Griffin Lake is the only lake of substantial size within an 80 kilometer (50 mile) radius and is important for waterfowl breeding, hunting, and fishing. A major watershed and lake cleanup project is planned for Griffin Lake to control aquatic weeds, improve water quality flowing into the Yakima River, increase waterfowl production, and recover the resident fishery. Today, pesticide/sediment laded water from agricultural lands flows into the lake and subsequently into the Yakima River.

This multi-agency cooperative project which involves partial funding from BPA, Ducks Unlimited, Pheasants Forever, WDFW Duck Stamp Program, NRCS, and local irrigation/water quality districts is designed to filter out pollutants before they reach the Yakima River. The project includes the construction of additional ponds and associated wetlands. The largest share of the funding for this restoration effort comes from a North

American Wetlands Conservation Act Grant (NAWCA), which is administered by the YIN. Three projects have been approved for NAWCA funding:

1. Wetland enhancements and construction of catch basins and 17 culverts to treat and direct water flowing into Giffin Lake
2. Installation of a lift pump and construction of "Bio Filters" to treat drain water flowing into Giffin Lake
3. Installation of a pump station and pipeline below the outlet at Giffin Lake and construction of about 70 acres of moist-soil management paddocks.

BPA participation includes funding aquatic vegetation control, wetland enhancements, and annual operation and maintenance. In addition, mitigation funds are used to staff the wildlife area and pay for enhancement and O&M activities on upland sites.

Sunnyside Unit Land Acquisition for Lower Snake River Compensation

Two parcels were purchased and developed with mitigation funds from United States Corps of Engineers (COE) for off-site Lower Snake River Compensation. The Brady property was purchased under the Element Z portion of the Snake River mitigation program to provide public fishing access to the Yakima River. The site encompasses approximately 35 hectares (86 acres) and provides about 0.8 kilometers (0.5 mile) of river frontage. The formal name for this site is the Sulphur Creek Public Fishing Area, named for an adjacent geographic feature. Development plans include a parking lot, fencing, well and irrigation development, and shrub plantings. Development activities are funded by the COE. The U.S. Fish and Wildlife Service (USFWS) funds operation and maintenance activities on this parcel through a Pittman-Robertson federal aid contract.

Similarly, the Vance property was purchased under the Element Z portion of the Lower Snake River Compensation Program to provide public fishing access to the Yakima River. This site encompasses approximately 47 hectares (116 acres) and provides access to about 1.2 kilometers (0.75 mile) of river frontage. The Vance property is located approximately 3.2 kilometers (2 miles) northeast of Mabton, Washington. Development plans include a parking lot, footpath and bridge, signs, fencing, habitat development, irrigation systems and shrub plantings. As with the Brady property, development activities are funded by the COE. Operation and maintenance activities are funded by USFWS.

Rattlesnake Slope Unit Wildlife Habitat Enhancement Project

The Washington State Energy Facility Site Evaluation Council (EFSEC) in its Site Certification Agreement for the Washington Public Power Supply System Nuclear Projects Number 1 and 2 at Hanford provided for the protection and mitigation of wildlife impacted by the projects. In 1987, EFSEC accepted a mitigation plan that would improve wildlife habitat on the nearby Rattlesnake Slop Unit of the Sunnyside Wildlife Area.

In 1987 the WDFW entered into mitigation with the Washington Public Power Supply System (WPPSS) for habitat loss in the construction of atomic power plants. A project agreement was developed and approved. Project activities included:

1. Upgrading and use of the existing well located in the northwest corner of the area.
2. Installing a drip irrigation system consisting of:
    A. Approx. 10 miles of PVC under ground water line plead out on three sections.
    B. Several miles of wire and eleven electric valves that run off an automatic timer.
    C. Forty-one shrub plots approx. 1/10 acre each.
    D. Approx. one mile of above ground drip irrigation tube.
    E. 14,000 shrubs.
    F. 14 wildlife-watering devices throughout the Unit.

In 1989, the system was completed and 2500 shrubs were planted that fall. The remainder of the shrubs was planted in the spring and fall of 1990. Extensive range fires during the summer of 2000 burned thousands of acres including the Rattlesnake Slope Unit. All enhancement efforts were reduced to ash. Some areas were reseeded in the fall of 2000. Rehabilitation efforts will continue for several years and include herbaceous seedings, shrub plantings, and weed control efforts. Through EFSEC, WPPSS funds the development, operation, maintenance, and monitoring activities.

Thornton Unit Vegetation Restoration Project

Thornton was acquired and is presently managed for mule deer, upland birds, transitory elk (the Hanford herd), sage grouse, and other shrub-steppe obligate species. When purchased, the unit consisted of 526 hectares (1,300 acres) of dryland cropland (small grains) with the remainder in shrub-steppe habitat. In 1997, 242 hectares (598 acres) of agricultural land was seeded to grass under the Conservation Reserve Program (CRP). In 1998 an additional 276 hectares (683 acres) were approved for inclusion into the CRP program. By the end of 1999, all croplands were converted to native-like vegetation.

Artificial Production

In 1982, the Council first encouraged BPA to "fund the design, construction, operation, and maintenance of a hatchery to enhance the fishery for the Yakima[22] Indian Nation as well as all other harvesters" (NPPC, 1982). In 1984, the Council provided further direction by recommending development of a master plan for the YKFP. Supplementation research was added to its stated fish production objectives. The proposed YKFP master plan, reviewed by the Council in 1987, provided the conceptual framework for the project, including types of fish and numbers to be produced, facility descriptions, management structure, schedule, and steps for evaluating the success of planned activities (Fish Management Consultants, 1987).

Following Council review, preliminary design work studies were begun to collect additional information needed for project planning. In 1990, the Preliminary Design Report (BPA, 1990b) was completed. Study results indicated that production facilities could be built in the Yakima River Basin to supplement natural production, provide harvest benefits, and gain knowledge about supplementation techniques of benefit to the entire region (BPA, 1990b).

In conjunction with the Preliminary Design Report on the YFP, an EA was prepared on the siting and construction of central, satellite and trapping facilities for supplementing anadromous fish populations in the Yakima and Klickitat River Basins (BPA, 1990a). The EA found that no significant environmental impacts would result from this portion of the proposed action, and the U.S. Department of Energy (USDOE) issued a Finding of No Significant Impact (FONSI) in April 1990.

Due to the large number of comments on the EA, BPA prepared and then issued a Draft EIS (DEIS) for the YFP in October 1992. After reviewing the comments, BPA concluded that additional work and a revision in the scope of the project were needed.

The Revised Draft EIS (RDEIS) presented in May of 1995, for public review and comment, a description of the revised YFP alternatives and additional information that was not included in the YFP DEIS.

The alternatives addressed in the FEIS are summarized as follows:

- Under Alternative 1, the project managers would conduct supplementation activities on upper Yakima spring chinook.

[22] Previously accepted spelling for the Yakama Indian Nation.

- Under Alternative 2, project managers would conduct both supplementation activities on upper Yakima spring chinook *and* a study to determine the feasibility of re-establishing a naturally spawning population and a significant fall fishery for coho in the Yakima River Basin. This is the preferred alternative.
- Under the No Action Alternative, no supplementation or study activities would be funded by BPA in the Yakima River Basin under these auspices, and no facilities would be constructed.

The FEIS was completed and the Record of Decision was signed in March on 1996.

Columbia River Fish Management Plans and Yakima Fish Production

Some fishery mitigation activities are currently taking place in the Yakima River Basin under the auspices of the CRFMP. This fish conservation and management plan describes production and harvest management actions that have been agreed to by all the parties to the *United States v Oregon* treaty fishing rights case. The parties to the original lawsuit and the CRFMP are the states of Oregon, Washington, and Idaho; the United States through representation by the NMFS and the U.S. Fish and Wildlife Service (USFWS); the four Columbia River Treaty Tribes (YIN, Confederated Tribes of the Warm Springs Indian Reservation, Umatilla, and Nez Perce tribes); and, to a limited extent, the Colville and Shoshone-Bannock tribes. Commercial, recreational, and traditional tribal fisheries in the mainstem Columbia River are managed under CRFMP provisions. The fish production and harvest provisions of CRFMP are intended to assist in the rebuilding of upper Columbia River chinook, sockeye, coho, and steelhead runs, while assuring an equitable sharing of harvestable fish between treaty and non-treaty fisheries.

Current CRFMP-sponsored activities in the Yakima River basin include programs for both fall chinook and coho salmon. The fall chinook program includes the annual production and release into the Yakima of 1.7 million smolts from the Little White Salmon National Hatchery. Between 1983 and 1994 the smolts were transported and released directly into the Yakima River. The YIN, with funds provided under the Mitchell Act program, has developed acclimation facilities in the vicinity of Prosser Dam for final rearing and release of these fall chinook smolts. These facilities will be tested by the YIN in 1995, and are expected to be on-line by 1996.

Since 1987, under the mandate of the CRFMP coho program, the Oregon Department of Fish and Wildlife's (ODFW) Cascade Hatchery (near Bonneville Dam) has provided up to 700,000 early-run coho yearly for release into the Yakima River. This program is part of a larger effort to redistribute coho for release in upper Columbia tributaries rather than in the lower Columbia. In addition to the CRFMP releases, the YIN fisheries program transferred approximately 600,000 juvenile coho (pre-smolts) into the Yakima River Basin in 1995. These fish were available as a result of unanticipated surpluses at lower Columbia hatcheries. Of these, 210,000 were planted in the Naches River Basin; 60,000 were planted in Ahtanum Creek on the Yakama Reservation; and 330,000 were moved to the new acclimation facilities at Prosser to be released as smolts in the spring of 1996.

Harvest

The State of Washington, the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation regularly schedule fisheries in the Yakima River Basin. Each jurisdiction has retained the authority to regulate its fisheries upon approval of its respective governing bodies. Fishing regulations authorize fisheries and describe lawful gear, fishing area, notice restrictions, and other miscellaneous regulations for fisheries enforcement purposes. All fisheries are monitored and enforced by agencies of the respective jurisdictions to ensure compliance and to provide accurate in-season accounting of harvest. Fisheries are routinely coordinated and fishery data shared between the co-management authorities via the United States v. Oregon harvest management process.

Tribal Fisheries

The majority of tribal fishing effort occurs in the spring below four irrigation diversion dams (Horn Rapids, Prosser, Sunnyside, and Wapato) during a fishery typically open from early April through mid-June from the mouth of the Yakima River upstream to the Wapato irrigation dam just south of Union Gap. With the implementation of the Cle Elum Supplementation and Research Facility, monitoring of tribal spring chinook fisheries in the Yakima River Basin has been increased with harvest monitors observing the fishery for a total of nearly 1200 hours in 1999 and nearly 2000 hours in 2000. The spring chinook fishery has been sampled for biological and stock composition purposes since 1999. A tribal fishery is also open on the Yakima River during the fall with tribal monitors typically recording over 100 hours of observation of the fishing effort and harvest. However, very little effort and virtually no harvests have been observed in these fall fisheries in recent years.

At other times of the year, the Yakima River and selected tributaries within the Yakama Reservation are open to fishing by tribal (and sometimes by non-tribal) members. Regulations are promulgated annually specifying closures at times and places where steelhead spawning is known to occur. Since fishing effort and success in these fisheries are very sporadic, there is no routine monitoring program. Harvest is assumed to be minimal in these fisheries.

State Fisheries

Estimated annual harvests of spring chinook and steelhead in tribal and non-tribal fisheries in the Yakima River Basin in recent years are given in Tables 48 and 49.

Table 48. Spring chinook harvest in the Yakima River Basin, 1982-Present.

	Tribal					Non-Tribal					Total					
	Below Prosser		Above Prosser			Below Prosser		Above Prosser			Below Prosser		Above Prosser			Harvest Rate
Year	Adults	Jacks	Adults	Jacks	Total	Adults	Jacks	Adults	Jacks	Total	Adults	Jacks	Adults	Jacks	Total	-------
1982	88		346		434						88	0	346	0	434	23.8%
1983	72		12		84						72	0	12	0	84	5.8%
1984	119		170		289						119	0	170	0	289	10.9%
1985	321		544		865						321	0	544	0	865	19.0%
1986	530		810		1340						530	0	810	0	1340	14.2%
1987	359		158		517						359	0	158	0	517	11.6%
1988	333		111		444						333	0	111	0	444	10.5%
1989	560		187		747						560	0	187	0	747	15.2%
1990	131		532		663						131	0	532	0	663	15.2%
1991	27		5		32						27	0	5	0	32	1.1%
1992	184		125	36	345						184	0	125	36	345	7.5%
1993	44		85		129						44	0	85	0	129	3.3%
1994	0		25		25						0	0	25	0	25	1.9%
1995	0		66	13	79						0	0	66	13	79	11.8%
1996	100		350	25	475						100	0	350	25	475	14.9%
1997	0		575		575						0	0	575	0	575	19.2%
1998	0		188		188						0	0	188	0	188	9.9%
1999	8	0	312	283	603						8	0	312	283	603	21.7%
2000	90	0	2181	86	2357			92	8	100	90	0	2273	94	2457	12.9%

Table 49. Steelhead in the Yakima River Basin, 1983-1999

Juvenile Out Migration						Adult Returns					Adult Harvest		/1		Hatchery Brood
Cal. Yr.	Wild	Hatch.	Total	%Wild		Run Yr.	Prosser	Wild	Hatch.	Wild%	Tribal	Sport	Escape.	Redds	Collection
						1983-84	1,140	911	229	79.9%	28	756	356		
						1984-85	2,194	1,975	219	90.0%	24	1,481	689		
						1985-86	2,235	2,012	223	90.0%	5	702	1,408		120
						1986-87	2,465	1,984	481	80.5%	6	514	1,822		123
						1987-88	2,840	2,470	370	87.0%	0	395	2,365		80
						1988-89	1,162	1,020	142	87.8%	3	142	864	451	153
1988	42,522	14,636	57,158	74.4%		1989-90	814	686	128	84.3%	45	121	539	325	109
1989	22,345	5,056	27,401	81.5%		1990-91	834	730	104	87.5%	0	28	782	160	24
1990	21,805	6,499	28,304	77.0%		1991-92	2,265	2,014	251	88.9%	2	146	2,095		22
1991	21,309	612	21,921	97.2%		1992-93	1,184	1,104	80	93.2%	0	72	1,089		23
1992	33,096	549	33,645	98.4%		1993-94	554	540	14	97.5%	0	3	551		
1993	17,165	3,109	20,274	84.7%		1994-95	925	838	87	90.6%	0	0	925		
1994	17,977	602	18,579	96.8%		1995-96	505	451	54	89.3%	15	5	485		
1995	17,765	16	17,781	99.9%		1996-97	956	818	138	85.6%	0	0	956		
1996	43,366	14	43,380	100.0%		1997-98	1,069	894	175	83.6%	0	50	1,019		
1997	44,631	0	44,631	100.0%		1998-99	1,070	1,018	52	95.1%	0	12	1,058		
1998	85,360	0	85,360	100.0%											
1999	38,266	0	38,266	100.0%											
Average:	33,801	2,591	36,392	1			1,388	1,217	172	1	8	277	1,063		

1. Spawning Escapement is Prosser Dam count minus harvest and hatchery broodstock collections which occurred in 1985-86 through 1992-93 run years.

Water

In August of 2000 Governor Locke requested that James Waldo prepare a proposed water investment action agenda for the Yakima Basin to substantially improve water supply, water quality and fish benefits, while reducing conflicts among the water users.

In preparing this action agenda, Mr. Waldo worked with the cities, counties, conservation districts, irrigation districts, Tri-County Water Resource Agency, state agencies, the Yakama Nation, the Bureau of Reclamation and staff from the Bonneville Power Administration. He asked all of them to submit proposed projects that would address the three goals of improving water quality, fisheries habitat and water system supply and reliability. The proposed projects were circulated in a draft report to the same broad cross-section of governments.

Over 85 project proposals, valued at just over $300 million, were submitted and considered. The Waldo report recommends that 63 of these projects be considered in the near-term and funded at approximately $132 million. Projects were reviewed individually, and in various combinations, to evaluate their benefits for the Yakima Basin. Recommendations were reviewed to ensure they would be consistent with and compatible with the federal planning effort done under the federal Yakima River Basin.

(See Table 50. Current water quality monitoring activities in the Yakima River Basin [pdf format]).

Water Enhancement Project Act, the planning done to date under the state 2514 process, projects previously funded by BPA, and the fisheries and planning ideas from the Yakama Nation The cover letter of the report states that if these recommendations are implemented the water quality, the fisheries habitat and the water management system of the Yakima Basin will be vastly improved over what it is today. Both the economy and the environment of the area will be enhanced. Conflicts between municipal and agricultural activities, and fisheries and aquatic resources will be greatly diminished.

In the lower basin, the recommended projects will provide substantial improvements for fisheries and water quality, particularly through actions to reduce temperature and sediment impacts. The water quality projects are aimed at both urban and agricultural actions. The Kennewick Irrigation District’s pump exchange is a key action to making significant changes in water temperature and flow levels, and to reduce potential long-term conflicts between fish and agriculture uses in the district’s service area. At an estimated cost of $50M, the Pump Exchange is by far the most expensive project we recommended. The funding recommendations in the lower basin also target habitat protection, restoration and acquisition in the lower basin.

In the region of the mainstem of the mid-Yakima River, beginning at the Wide Hollow/Union Gap, the major actions will include relocating gravel mining from the floodplain, acquisition of important habitat, and reconnection of habitat that has been disconnected from the mainstem. These actions will not only improve the fish habitat, but also improve water quality. Various entities in the watershed are already considering or actively pursuing acquisition of riparian properties critical to fish and wildlife habitat restoration. A variety of project proposals have identified the Yakima River floodplain through the Selah Gap and Union Gap areas and the lower areas of Wide Hollow Creek as priority locations for these acquisitions and restoration efforts.

Longer-term benefits of property acquisition and management include restoring the groundwater recharge function of the floodplain areas. This will be pursued once basic habitat restoration projects have been completed.

Not all of the entities who plan to make acquisitions have the capacity or authority to take on the responsibility for long-term care of these properties. Additionally, these properties are likely to span jurisdictions. Therefore, purchasing entities will need to work together to develop a long-term framework for property management and environmental stewardship of these lands. Our recommendations include a first step toward that goal. Short- and long-term coordination among the purchasing entities is essential in order to ensure that wetland areas and other critical floodplain functions are "reconnected" and to ensure that entities are not unnecessarily competing on the price of key purchases.

Relocating the gravel mining activities will also augment and improve water quality actions in this stretch of the river, which include major investments in addressing urban water quality problems through a variety of means.

In the Naches arm of the Yakima River, the recommended projects focus on improving and protecting fish habitat, and increasing flows, principally through the Wapatox project. We also recommend investing in major improvements to address current fish passage barriers, diversions affecting the fisheries, and to invest in infrastructure to reduce conflicts.

In the Upper Yakima River mainstem, the focus is on reconnecting portions of the floodplain, protecting critical habitat, improving water quality, and embarking on a major effort in the Kittitas tributaries. Actions include projects proposed by the Bureau of Reclamation in the Manastash, Swauk, and Taneum creeks; the Department of Ecology's TMDL early implementation project on the Teanaway River, and significant commitments to screening small diversions in the Kittitas Valley. We are also recommending the acquisition of certain parcels because of their high habitat value. Finally, there are a number of major water quality improvements (both municipal and agricultural) recommended for the Kittitas Valley which will substantially improve water quality and will have secondary benefits for the fisheries resource.

The projects we are recommending are listed in geographical order beginning at the mouth of the Yakima River and proceeding up into the tributaries within the Yakima Basin. Our recommendations for funding levels and sources are listed in alphabetical order by the sponsoring entity.

Table 51. Funding recommendations for water investments in the Yakima basin

Project No.	Name	Sponsor	Funding Recommendation	Timeline	Funding Sources (Federal, State, and BPA)	Comments
27	Ahtanum Irrigation District Salmon Recovery Program	Ahtanum Irrigation District (AID)/North Yakima Conservation District (NYCD)	$900K	2001-2002	Bonneville Power Administration (BPA)	
3	Water Quality Improvement (Lower Yakima Basin)	Benton Conservation District	$2.45 Million	2001-2002	Federal and State Water Quality	
44	Taneum Creek Steelhead Supplementation	Bureau of Reclamation (BOR)	$100K	2000-2002	BOR	
42	Lower Manastash Creek Project	BOR	$150K	2001-2002	BOR	
52	Lower Swauk Creek Watershed Protection	BOR	$1.3 Million	2001-2004	BOR	
36	Wapatox Power Plant Purchase	BOR	Under Negotiation	2000-2001	BOR and BPA	
21	Alternatives to Gravel Mining within Yakima River Floodplains	BOR	To be negotiated	2000-2002	BOR, BPA, State	• BOR primary funding. • BPA fund up to 50/50 match for acquisition and relocation of gravel mining from the floodplain. • Active participation of local governments to assist with relocation. • Potential Department of Natural Resources (DNR) replacement sites. • Ecology fund $200K interim water quality State respond to local governments $150K
6	Grandview Comprehensive Drainage Program	City and Port of Grandview, Yakima County Sunnyside Valley Irrigation District (SVID)	$150K	2001-2002	State and Federal Water Quality	
40	Ellensburg Replacement Well Study	City of Ellensburg	$45K	2001	Ecology	
39	Ellensburg Storm Drain Outfall Treatment	City of Ellensburg	$1 Million	2001-2002	State and Federal Water Quality	

Project No.	Name	Sponsor	Funding Recommendation	Timeline	Funding Sources (Federal, State, and BPA)	Comments
38	Ellensburg Treatment Plant Outfall Modifications	City of Ellensburg	$150K	2001-2003	State and Federal Water Quality	
41	Ellensburg Stream Inventory for Fisheries Actions	City of Ellensburg	$55K	2001	BPA	
7	Sunnyside Drainage Improvement Project	City of Sunnyside	$100K	2001-2002	State – Water Quality	
8	Sunnyside Wastewater Plant Improvement Project	City of Sunnyside	$650K $11.4 Million	2001-2002 2003-2004	State and Federal Water Quality	
29	Aquifer Storage and Recovery	City of Yakima	$125K	2001	State (Ecology) and BOR	
26	Critical Lands Protection – City of Yakima	City of Yakima	$2.2 Million	2001-2002	State and BPA	
30	Fruitvale Power Canal Intake Relocation and Habitat Restoration	City of Yakima	$6 Million	2001-2003	State and BPA	
24	Water Quality Improvement – Water Quality Ponds	City of Yakima	$3.2 Million	2001-2003	State and Federal Water Quality	
34	Water Treatment Plant Intake Modification	City of Yakima	$550K	2002	State	
25	Yakima Regional Wastewater Treatment Facility – Water Quality Protection	City of Yakima	$3.5 Million	Commence implementation 2001	State and Federal	Funding to protect groundwater and recognize current water quality improvement actions
56	Teanaway Riparian & TMDL Project	Ecology	$200K	2001-2003	BPA	
28	Ahtanum Watershed Study -- IFIM Study	Ecology/AID with fish agencies	$400K	2001-2002	Ecology and Salmon Recovery Funding Board (SRFB)	
48	Kittitas Valley Irrigation Diversion Screens	Kittitas County Conservation District (KCCD)	$3 Million	2001-2004	BPA	50 fish screens

Project No.	Name	Sponsor	Funding Recommendation	Timeline	Funding Sources (Federal, State, and BPA)	Comments
51	Kittitas Valley Irrigation System Efficiency Improvements	KCCD	$300K	2001-2003	State and Federal Water Quality	
49	Upper Yakima Diversion Screening/Fish Passage Improvements	Kittitas County Water Purveyors (KCWP), Kittitas Reclamation District (KRD)	$4 Million	2001-2005	BPA	
50	Technical Support for Screening & Delivery System	KCWP, KRD	$400K	2001-2005	State and Federal Appropriations	$80K per year -- 5 years
47	Survey of Unscreened Diversions and Fish Passage Barriers in Upper Yakima	KCWP, KRD, KCCD	$30K	2001-2002	BPA	
2	Kennewick Irrigation District Pump Exchange	Kennewick Irrigation District /BOR	$50 Million estimated capital	2001-2003 2004-2006	BOR – Immediate State (5% capital cost) – Long-term BOR and BPA	• Feasibility study and right-of-way acquisition. • The State is a participant with BOR in the YRBWEP
45 & 55	Improved Water Quality Measures in the Kittitas Valley	KCWP, KRD	$375K	2001-2006	State and Federal Water Quality	
46	Irrigation District Delivery System Enhancements	KRD and KCWP	Estimated range $10-$20 Million	2002-2005	BOR, BPA, State and Federal Water Quality	
14	Sedimentation Basins	Roza Sunnyside Joint Board	$400K	2001-2003	State and Federal Water Quality	
5	Sulphur Creek Habitat	Roza Sunnyside Joint Board	$50K	2001-2003	BPA and SRFB	
16	Enclosed Conduit and Grainger Drain	Roza Sunnyside Joint Board	$1.3 Million	2001-2003	State and Federal Water Quality	
9	Buffer Zones – Yakima River	Roza Sunnyside Joint Board	$375K	2001-2003	BPA	
12	Mainstem Lower Yakima – BMPS – Water Quality Project	South Yakima Conservation District	$400K	2001-2004	State and Federal Water Quality	• $100K per year

Project No.	Name	Sponsor	Funding Recommendation	Timeline	Funding Sources (Federal, State, and BPA)	Comments
1	Habitat Restoration and Protection	Tapteal Greenway Association	$200K	2001-2002	BPA and State	
33	Selah Spray-Field – Yakima River Restoration	TreeTop, Inc.	$105K	2001-2002	SRFB -- $92K State and federal water quality for remainder	
57	Yakima Watershed Planning – Level II Assessment	Tri-County Water Resources Agency	$410K	2001-2002	State (Ecology)	
53	Cle Elum Reach – Purchase of Habitat	Washington Department of Fish and Wildlife (WDFW)	$4 Million	2001	BPA	
19	Union Gap Reach – Purchase of Habitat	WDFW	$45K	2001	BPA and SRFB	
35	Lower Naches Reach – Habitat Project	WDFW	$1 Million	2001-2002	BPA and SRFB	
32	Buckskin Slough – Habitat Restoration	WDFW	$77K	2001-2002	SRFB and BPA	
20	Spring Creek Passage and Habitat Restoration	WDFW	$25K	2001	SRFB	
54	Big Creek – Passage and Screening	WDFW	$70K	2001-2003	SRFB or BPA	
23	Wide Hollow Creek – Passage and Floodplain Restoration	WDFW	$1 Million	2001-2004	BPA and SRFB	
43	Wilson Creek/Matoon Lake – Protection and Acquisition	WDFW	$150K	2001	BPA	
62	Yakima Basin Inventory and Assessment – SSHIAP	WDFW	$125K	2001-2002	BPA	
37	Umtanum Creek	WDFW	$160K	2001	BPA	
58	Washington WEST (Watershed Ecology, Science and Technology)	Washington Grazing Lands Conservation Initiative	$5K	2001	State (Ecology)	
61	Water Acquisition to Enhance Critical Flows – Yakima River	Yakama Nation	$800K	2001-2005	BPA	

Project No.	Name	Sponsor	Funding Recommendation	Timeline	Funding Sources (Federal, State, and BPA)	Comments
17	Wapato Irrigation Project – Measurement and BMP	Yakama Nation	$2 Million	2001-2005	USDA – EQUIP and BIA	
15	Culvert Replacement – Yakama Reservation	Yakama Nation	$2.5 Million	2001-2005	BPA and BIA	
10	Toppenish Creek Dike Removal	Yakama Nation	$180K	2001-2003	BPA	
11	Fish Habitat Acquisition -- Yakama Reservation	Yakama Nation	$1 Million	2001-2004	BPA	
4	Satus Creek Revegetation – Native Bunch Grass	Yakama Nation	$60K	2001-2002	BPA	
22	Floodplain Gravel Mining Relocation	Yakama Nation Water	$75k	2001-2002	BPA	
59	Salmon Habitat Metrics Project	Yakama Nation and Central Washington University	$200K	2001-2003	BPA	
18	Critical Habitat Acquisition / Mid-Yakima River	Yakama Nation Fisheries	$500K	2001-2003	BPA	
13	Prioritization Plan for Toppenish and Simcoe Creeks	Yakama Nation Fisheries	$100K	2001-2002	BPA and SRFB	
60	Irrigation Diversion Bypass -- Outfalls and Wastewater returns	Yakama Nation Fisheries	$150K	2001-2003	BPA	Program design and pilots
31	Cowiche Watershed Passage, Restoration and Screening	Yakama Nation/WDFW	$150K	2001-2002	BPA and SRFB	
63	Rural Community Shoreline Program	Yakima Valley Conference of Governments	$50K	2001	State	

Passage

Survival and fish bypass effectiveness at Yakima basin fish screens constructed in the 1930's, 40's, 50's, 60's, and even as recently as the 1970's, are inadequate to assure that gravity water diversions are not depressing anadromous salmonid egg-to-smolt survival rates. Survival and bypass guidance at Pacific Corporations Wapatox Canal hydropower and irrigation diversion on the Naches River were quantified by Eddy (1988). This pre-Phase II facility (500 cfs, circa 1936) was studied in 1986 and 1987 and shown to guide less than 10 percent (0-7%) of marked, acclimated, hatchery-reared chinook fry (<60 mm FL) safely back to the river. Fingerling (60-90 mm) and yearling smolt size chinook (>90 mm) experienced incrementally better guidance that was clearly size related; 40-60 percent for fingerlings and 70-75 percent for yearlings. Low survival/guidance for small fish was attributed to canal entrainment caused by over-sized screen mesh openings and screen impingement caused by high approach velocity at the screen face, perpendicular screen orientation relative to canal flow, and poor hydraulic conditions at the fish bypass entrances. This electric-drive, drum screen facility, with an average approach velocity of 1.0 feet/sec (range: 0.8 -1.4 feet/sec) and 1/4" screen mesh openings, was designed primarily to protect larger, yearling size fish. These obsolete design criteria are representative of most pre-Phase II fish screens in the Yakima basin and throughout Washington. Some paddlewheel-driven drum screens were designed based on a 1.5 feet/sec approach velocity, thought to be necessary to provide adequate power to turn the paddlewheel, with total disregard for the biological needs of the fish.

At about the same time, the Washington Department of Fisheries (WDF), Washington Department of Game, and Centralia City Light Department contracted with the University of Washington Fisheries Research Institute, to perform laboratory swimming stamina tests of several salmon species including steelhead and resident rainbow trout (Smith and Carpenter, 1987). The research revealed that a design screen approach velocity of 0.4 feet/sec was necessary to protect emergent fry of the weakest species (steelhead, rainbow trout, pink & chum salmon) at low spring- time water temperatures (3-4^{o} C.). WDF adopted the 0.4 feet/sec approach velocity criteria in 1988. Oregon Department of Fish and Game and the National Marine Fisheries Service (NMFS) concurred with the findings and also adopted this conservative criteria.

In 1992, WDF conducted research on salmon fry entrainment through various types and sizes of screen material (Bates and Fuller, 1992). The results showed that that mesh openings greater than 0.125 inches allowed entrainment of salmon emergent fry. A similar study performed by Beecher and Engman (1995) testing steelhead and resident rainbow trout fry determined that a 3/32 inch (0.094) criteria was necessary to prevent entrainment. This conclusion was supported by an evaluation of the Dryden Canal fish screen (Wenatchee R.) in 1994 by the Pacific Northwest National Laboratory (PNNL) (Mueller et al. 1995). Although the Dryden screen was designed using the 0.4 feet/sec approach velocity criteria, it was constructed in 1993 using the applicable 0.125 inch mesh opening criteria. PNNL determined that 6 percent of wild summer chinook fry were entrained and in excess of 40 percent of rainbow trout were entrained.

Together these studies represent the scientific basis for the current regional fish screening criteria adopted in 1995 by NMFS and the Washington, Oregon, and Idaho fish screening programs [the principal regulatory agencies on the Columbia Basin Fish and Wildlife Authority (CBFWA) Fish Screening Oversight Committee (FSOC)]. Post-construction evaluations conducted by PNNL confirm that Yakima Phase II fish screens constructed to the current criteria and properly operated and maintained, protect fry from injury/mortality and achieve bypass guidance rates in the 90-99 percent range. Fish screen facilities with this high level of protection performance minimize a source of mortality that can reduce basin smolt production.

Obsolete fish screens from the 1930's, 40's, 50's and 60's must be replaced or updated to comply with current regional fish screen biological protection criteria adopted by CBFWA FSOC in 1995. The project objective is to provide protection approaching 100% for all species and life stages of anadromous (and resident) salmonids. Old screens in the Yakima basin, and in other Columbia River subbasins, may provide fair protection for large (4-6 inch long) yearling smolts, but poor protection for fry and fingerling life stages. Mortality of fry and fingerlings by irrigation diversions may reduce subsequent smolt production and inhibits efforts to restore depressed salmon and steelhead populations through natural production or hatchery supplementation. Biological evaluation of completed Phase II fish screen facilities by PNNL has quantified survival and guidance rates approaching 100%. Consequently, the state and federal fish agencies and the Yakama Indian Nation propose to complete replacement or upgrade of all obsolete fish screen facilities in the Yakima basin within the next 5 -7 years.

The following tables provide the screen sites included in Phase I and Phase II within the Yakima basin that are completed and operational (includes site name, flow rate in cfs), planned for construction, and eliminated from the program:

Table 52. Yakima River fish passage facilities improvement - Phase I

Site	Facility	Date Completed	Cost ($Millions)	Funded By	Status
Sunnyside	Screens	1985	2.9	BPA	Operational
	Ladders	1985	2.0	BPA	Operational
	Crest Raise	1986	0.1	BPA	Operational
Naches-Cowiche	Ladder and Screen	1985	0.5	City of Yakima	Operational; ladder being modified
Horn Rapids	Richland Canal Screen	1985	0.4	BPA	Operational
	Ladders & CID Screen	1986	1.6	State and USBR	Operational
Wapato	West Branch Ladder	1985	1.2	BIA	Operational; ladder gates being upgraded
	Screens	1986	2.8	BPA	Operational
	East Branch Ladders	1986	1.8	BPA	Operational; ladder gates being upgraded
Toppenish Creek/Satus Unit	Ladders & Screens	1986	1.6	BPA	Operational

Chandler Canal	Screens & Juvenile Facility	1987	7.7	USBR	Operational
Prosser	Right Bank Ladder	1986	1.2	USBR	Operational
	Right Bank Trap	1988	0.9	USBR	Operational
	Left and Center Ladders	1989	2.6	USBR	Operational; scheduled modifications for viewing windows
Roza	Screens	1988	11.4	USBR	Operational
	Ladders	1988	2.5	USBR	Operational
	Powerplant Wasteway Barrier	1987	0.8	USBR	Operational
Satus Creek	Ladder	1986		BPA	Operational
Toppenish Creek	Screen	1987	0.3	BPA	Operational
Marion Drain	Ladder	1988	0.2	BPA	Operational
Westside	Screen	1988	0.6	BPA	Operational
Easton	Screens	1989	4.7	USBR	Operational
	Ladder	1989	2.7	USBR	Operational
Town	Ladder&Screen	1989	1.6	BPA&USBR	Operational
Taneum Creek	Ladders & Screens	1989	0.8	USBR	Operational
Wapatox	Screens and ladder			PP&L	Operational

Table 53. Yakima River fish passage facilities improvement program - Phase II

Completed Facilities	**Date In Service**	**Comments**
Kiona Screen	1992	Abandoned due to flood - conversion to pump site
Naches-Cowiche Screen	1992	Operational
Gleed Screen	1993	Operational
New Cascade Screen	1993	Operational
WIP Lower Screen	1993	Operational
Snipes/Allen Screen	1993	Operational
Bruton Ditch Screen & Ladder Mods	1993	Operational
Taylor Screen	1994	Operational

Congdon Screen	1994	Operational
Kelley/Lowery Screen	1994	Operational
New Cascade Headgate Mods	1994	Operational
Bachelor Creek Screen, Adult Barrier & Pipeline	1994	Operational
WIP Toppenish Pump Screen	1995	Operational
Naches-Selah Screen	1996	Operational
Fruitvale Screen	1996	Operational
Vertrees No. 2 Sprinkler System to replace river diversion	1997	Operational
WIP Upper Screen & Access Bridge	1997	Operational
Yakima-Tieton Screen	1997	Operational
Union Gap Screen	1997	Operational
Bull Screen	1997	Operational
Ellensburg Mill Screen	1997	Operational
Clark Screen	1997	Operational
Lindsey Screen	1997	Operational
Foster-Natchez Pump & Pipeline	1998	To replace river diversion Operational
Younger Screen	1998	Operational
Old Union Screen	1998	Operational
John Cox Screen	1999	Operational
Moxee/Hubbard Pump	2000	To replace river diversion Operational
City of Yakima Screen Bypass Mods	2000	Operational
Knudson Div-Taneum Creek Channel Mods	2000	Operational

Facilities Under Construction	**Expected Date In Service**	**Comments**
Lewis Screen	2001	Construction in progress
LaFortune/Powell Screen	2001	Construction in progress
Wilson Creek/Bull Ditch Screen and Ladder	2001	Construction in progress

Facilities Scheduled for Construction	**Expected Date In Service**	**Comments**
Naches-Cowiche Ladder Mods	2001	Designs 50% complete
Fogarty Screen	2002	Delayed due to right-of-way problems
Selah-Moxee Screen	2002	Delayed due to right-of-way problems
Scott Screen	2002	Delayed due to right-of-way problems
Packwood Screen	2002	Designs 25% complete
Tjossem Screen	2002	Delayed due to major biological plan revisions
Toppenish Refuge Screens/Ladders	2002	Plan undefined - may eliminate
Chapman-Nelson Screen	2001	

Sites Screened by WDFW	**Date In Service**	**Comments**
Brewer Screen	**1988**	**Phase II**
McDaniels Screen	**1993**	**Federal Screen**
Emerick Screen	**1996**	**Phase II**
Anderson Screen	**1996**	**Phase II**
Tennant Screen		
Beck Screen		**Candidate for Phase III**
Contratto Screen		**Candidate for Phase III**
Sinclair-Cobb Screen		**Abandoned**
Gnavaugh Screen		**Abandoned**
Stevens Screen	**1996**	**Phase II**

Eliminated from Phase II Program	**Comments**
Boise Cascade	Sufficient groundwater flow to close headgate permanently
Musetti Screen	Candidate for Phase III
Ballard Screen	Phase II funding - to be completed 2001
Giustetti-Contratto Screen	Candidate for Phase III
Contratto-Banchi Screen	Candidate for Phase III
Bussoli Screen	Candidate for Phase III
Cooper-Masterson Screen	Pump replaced gravity diversion
Brockbank Screen	Abandoned
Peterson Screen	Pump replaced gravity diversion
Seaton Screen	Pump replaced gravity diversion
Bugni Screen	Candidate for Phase III
Giustetti-Bussoli Screen	Candidate for Phase III
Favro Screen	Abandoned
O'Connor Screen	Abandoned
Upper Shattuck Screen	Abandoned
Lower Shattuck Screen	Abandoned
Holwegner Screen	Abandoned

Wilson Creek

Work began in fall of 1999, primarily in lower Wilson Creek. Historically, Wilson Creek was believed to be a large producer of anadromous fish. The watershed is roughly 400 square miles, but fish access was limited to only the lowest six miles. Several projects have been implemented to restore juvenile and adult passage to 12 miles. Within this area, work continues to screen irrigation diversions and to further improve passage. One large project to screen 40 cfs is currently being constructed under subcontract with WDFW and BOR.

Work scheduled for the 2001 includes:

1. Improve an irrigation delivery system, by pressurizing the system, consolidating four unscreened diversions and eliminating a seasonal passage barrier.
2. Convert three unscreened gravity diversions to pump diversions, to save water and prevent entrainment into irrigation ditches.
3. Transfer a point of diversion from Wilson Creek to a pond, and install pipe, to allow the removal of an unscreened gravity diversion.

4. Install two siphons, to eliminate commingling of irrigation water with creek water, in turn preventing entrainment and water quality problems.

Manastash Creek

Manastash Creek suffers from problems similar to Wilson Creek, but instream flows in the lowest five miles are entirely lacking during the peak of the irrigation season. A preliminary assessment of the barriers and unscreened diversions has been conducted, and diversionary quantities have been measured at all diversions. During 2001, Yakama Nation biologists will continue collecting data and working with landowners to develop the appropriate restoration solution for passage, screening, water quality and instream flows.

Tucker Creek

Tucker Creek could provide productive habitat for steelhead and resident trout, were it not for one barrier and diversion. An assessment has been conducted, and an engineered design for a series of boulder weirs has been developed. In 2001, permits will be secured and the project will be constructed.

Wide Hollow Creek Diversion Dam

WDFW has improved fish passage for Wide Hollow creek Diversion Dam at Perry Technical Institute.

Teanaway Junction Access Area

In-stream structures and weirs were constructed on WDFW property on a tributary to the Teanaway River to improve access

Enforcement

Washington Department of Fish and Wildlife Enforcement

WDFW Yakima Basin Enforcement Program employs twelve officers, three sergeants, and one captain who are primarily responsible for enforcing Titles 75 and 77—the Fish and Wildlife Code—to ensure compliance with licensing and habitat requirements, enforce prohibition against the illegal taking or poaching of fish and wildlife and protect public safety. The WDFW Enforcement Program is also charged with enforcing other codes including 70.93-Forest Protection Act, 76.04-water craft registration and 88.02 and 43.5-boating safety education. Officers hold federal U. S. Fish and Wildlife and National Marine Fisheries Service commissions and have jurisdiction over federal violations, the most important of which are the Endangered Species Act and the Lacey Act. Officers are called on to assist their local city/county, and other state and federal law enforcement agencies, and tribal authorities.

Statewide data show that 83% of an officer’s time is devoted to natural resource law compliance. Activity figures for 2000 in Region 3, which is Benton, Franklin, Yakima, and Kittitas counties, show that 44% (13,717) of the contacts made were fish related, 17 % (5,404) were wildlife related, 11 % (3,605) were habitat/lands management related, and 8 % (1100) were wildlife damage control contacts. (The remainder were contacts not related to natural resources.) Officers made 31,156 contacts, 1,583 arrests, and 315 warnings in 2000.

Education

Agricultural Water Quality Education Program

In 1998, the Washington State Department of Ecology implemented a project to provide water quality education and technical assistance to irrigators and farmers in the Yakima

River Basin. Ecology water quality specialists visit agricultural areas throughout the Basin during the growing season to help identify and solve potential pollution problems.

Bureau of Reclamation Environmental Training Project

The Yakima Basin Environmental Education Training Project was initiated in 1991 and is funded by the Bonneville Power Administration. The focus of the program is to provided teachers with relevant, hands-on environmental education training meeting the Essential Academic Learning Requirements (EALRs). The project's goals, objectives and strategies are summarized in Goal 4, Objectives 12 and 13 of this document.

The Yakima Basin Environmental Education Project works with over 33 schools from districts throughout the Yakima Basin. In addition, the environmental project has formed close working partnerships with a variety of public and private entities, including the Yakama Nation, Bureau of Reclamation, Washington Department of Fish and Wildlife, US Fish and Wildlife, U.S. Forest Service, City of Yakima, Tree Top Corporation, Boise Cascade Corporation, PacifiCorp, North Yakima Conservation District, Department of Ecology and WSU Extension.

The Yakima Basin Environmental Education project directly addresses Washington Goals for Environmental Education established by the Washington Legislature. RCW 28A.230.020 states: All common schools shall give instruction in...science with special reference to the environment. In addition, WAC 180-50-115 states: A[6] Pursuant to RCW 28A.230.020, instruction about conservation, natural resources, and the environment shall be provided at all grade levels in an interdisciplinary manner through science, the social studies, the humanities, and other appropriate areas with an emphasis on solving the problems of human adaptation to the environment.

Environmental training projects include:

Sportsman Park Nature Trail

This nature trail into a wetland involves students from East Valley School District in the development of interpretative signs explaining plants and animals along the trail as well as designing explanations of other interesting plants and animals in the park for display in other areas in the park. Partners in this project include North Yakima Conservation District, EPA, US Forest Service and Washington State Parks Department.

Cowiche Creek

This site along the Cowiche Creek Conservancy Trail is used by Roosevelt Elementary, Nob Hill Elementary and Marcus Whitman Elementary for release of their salmon fry, as well as water quality monitoring, litter cleanup and wildlife investigations. Partners are Washington Fish and Wildlife, Yakama Nation and Bureau of Reclamation.

Powerhouse Nature Trail

This newly developed trail through a major development in Yakima will provide opportunity for students from the Yakima Lab School to plan and implement an urban wildlife setting. Working with members of the Audubon Society, Yakima City Works Dept. and the local community, students will help to establish and maintain this new urban wildlife area.

Highland High School

This project addresses the possibility of building and maintaining a functioning wetland available to the community as an educational resource, which also treats stormwater runoff collected from the roof of the building prior to its release into Cowiche Creek.

Fullbright Park

Salmon tubes are planted at Fullbright Park in the fall by PACE Alternative School, Wapato School District. Salmon in the classroom coho from PACE and Wilson Middle School are released. Partners include Union Gap City Parks, North Yakima Conservation District, Washington Fish and Wildlife, Bureau of Reclamation and the Yakama Nation

Salmon in the Classroom

Twenty-four classrooms throughout the valley raise coho salmon and release them into area streams with the cooperation of Yakama Nation Fisheries, Washington Dept. of Fish and Wildlife, US Forest Service and the Bureau of Reclamation..

Tapteal Greenway Education Projects

Since 1995, Tapteal Greenway has provided educational opportunities in the Greenway and in the classroom. Examples of past and present projects include:

- On-going water quality instruction through K-12 classrooms and home-schoolers, reaching several hundred students, teachers and parents, in the classroom and the field,
- Hikes for Tykes habitat appreciation program (on-going) for pre- and grade-school kids;
- Summer programs teaching natural and human history, water resource issues, and engaging students in stewardship activities, and civics lessons through presentations to Parks Commission. Partnered with the Benton Franklin Volunteer Center and Columbia Industries to offer leadership camps serving primarily low income and minority youth;
- Environmental arts projects with the Benton/Franklin Boys and Girls Clubs; and Produced and distributed 200 page high school curriculum package on the Lower Yakima River to all the local high schools and several middle schools from Prosser to Burbank. Content includes geological, cultural, and natural history of the area, detailed information on flora and fauna identification, water quality monitoring basics, and well as lesson plans for students;

Recreation

WDFW Warmwater Gamefish Recreational Projects

The WDFW Warmwater Gamefish Enhancement Program has completed several projects to improve public access to recreational fishing opportunities. The Youth Fishing Program has been expanded to include the establishment of new waters for juvenile access, improved access at existing juvenile waters, and the sponsoring of several new Youth Fishing Events across the state. Planning and improvements have been completed to provide more public access on over two dozen state waters, including fishing piers, improved launches, a new public access on Sprague Lake, and other similar projects. The Warmwater Gamefish Enhancement Program is continuing to develop and maintain warmwater fishing opportunities in urban settings, as well as other locations in the basin.

Past Research, Monitoring, and Evaluation

Completed projects are described below. For current and on-going research, monitoring, evaluation and planning activities, see the Present Subbasin Management section.

Healthy Ponderosa Pine Working Group

A working group of cooperating biologists from agencies and industry (Healthy Ponderosa Pine Working Group – HPPWG) is initiating research on species associated with old pine forest habitats, such as flammulated owls, and the status of old pine habitat in Washington. Preliminary survey results indicate that most of the old pine habitat is already gone from Washington (R. Crawford, DNR, pers. comm.)

Sockeye Reintroduction

The Cle Elum Anadromous Salmon Restoration Feasibility Study was conducted by National Marine Fisheries Service (NMFS) from 1987 to 1993 to determine if sockeye salmon could be reintroduced to Cle Elum Reservoir. Adults were collected in Lake Wenatchee, transported to and spawned in Seattle, where the juveniles were reared. Smolts were released above and below the dam to determine if smolts could get out of the reservoir. A summary of research by Flagg and Ruehle was published in 2000.

Fish Screen Facilities

The Bonneville Power Administration (BPA), the United States Bureau of Reclamation (USBOR), and the Washington State Department of Ecology are funding the construction and evaluation of fish passage and protection facilities at irrigation and hydroelectric diversions in the Yakima River Basin. Under Phase I of the Yakima River Basin Fish Passage And Protective Facilities Program, improvements to existing fish passage facilities and installation of new fish ladders and fish screens at 16 of the largest existing diversion dams and canals were begun in 1984 and were substantially completed by the fall of 1989. Under Phase II of this project 31 other fish protection facilities have been constructed and various other facilities are under construction or in the design and planning phases. This construction implements Section 803 (d) of the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program (NPPC 1987). The program provides offsite enhancement to compensate for fish and wildlife losses caused by hydroelectric development throughout the Columbia River Basin and addresses natural propagation of salmon to help mitigate the impact of irrigation in the Yakima River Basin.

Pacific Northwest National Laboratory (PNNL) has been evaluating the effectiveness of fish screening facilities in the Yakima basin since 1985. These BPA-funded evaluations serve to ensure that facilities constructed for the purpose of fish protection are indeed protecting fish. Screen site evaluations provide information on whether a facility was designed and is being operated and maintained to meet fish protection criteria established by the National Marine Fisheries Service (NMFS). When problems are encountered (e.g., broken seal or clogged bypass system), PNNL reports the problem to the agency maintaining that facility (typically, USBOR for Phase I facilities on the mainstem Yakima River and the Washington Department of Fish and Wildlife for the Phase II facilities on tributaries), and these agencies correct the problem. PNNL has also conducted studies of fish screen design and operation to support design of more effective structures (Abernethy et al. 1996; Neitzel et al. 1997).

Specifically, evaluations were and are being performed to determine if:

- flows in front of screens promote fish bypass without chance of delay or impingement
- screens are adequately sealed to prevent fish injury or entrainment
- screen submergence levels preclude fish roll-over or entrainment, yet promote debris removal
- bypass outfall conditions promote safe fish access to the river, and
- conditions in front of screens deter predation of juvenile salmonids.

Using a combination of mark-recapture studies, underwater videography, and velocity measurements to quantify these performance measures, PNNL evaluated Phase I screening projects between 1985 and 1990. The following sites were evaluated:

- Columbia (Abernethy et al. 1989)

- Chandler (Abernethy et al. 1990)
- Easton (Abernethy et al. 1990)
- Richland (Abernethy et al. 1989; Neitzel et al. 1986; 1988)
- Roza (Abernethy et al. 1989)
- Sunnyside (Abernethy et al. 1989; Neitzel et al. 1985; 1990a)
- Toppenish/Satus (Neitzel et al. 1986)
- Toppenish Creek (Neitzel et al. 1990a)
- Town Ditch (Neitzel et al. 1990c)
- Wapato (Abernethy et al. 1989; 1990; Neitzel et al. 1988; 1990a; 1990b)
- Westside Ditch (Abernethy et al. 1989; Neitzel et al. 1990b; 1990c)

In general, mark-recapture studies at Phase I sites showed minimal descaling and relatively rapid passage times for chinook salmon and slightly more descaling and longer passage times for steelhead. Most sites showed minimal or no entrainment. However, two exceptions to this were Town Canal and Westside Ditch, where up to 25% of the age-0 chinook salmon (< 36 mm long) were found to pass through the screens.

In the late 1990s, as Phase II of the fish passage improvement program in the Yakima basin got underway, PNNL began to evaluate these sites as they were constructed. These Phase II evaluations continue on an annual basis and now involve 21 sites on tributaries within the Yakima basin (Blanton et al. 1998; 1999; 2000). Phase II sites are shown in Figure 81. Due to the permitting and ecological implications with releasing large numbers of fish to evaluate the effectiveness of screening facilities, no mark/recap studies are currently being conducted. The integrity of the site is evaluated by checking seals/measuring velocities/inspecting bypasses, screen submergence, etc PNNL now employs a combination of velocity measurements, underwater videography, and a site checklist approach to evaluating whether facilities are in compliance with NMFS criteria.

At Phase II sites, water velocity conditions at the screen sites generally met fish passage criteria set forth by the NMFS. Although velocities often fluctuated from one sampling location to the next, average sweep velocities typically exceeded approach velocities and increased toward the bypass. Mean approach velocities were below the NMFS criteria of $\leq$ 0.4 feet per second (fps) at most sites. High approach velocities may cause juvenile fishes to become impinged on the screen material. Depending on the type of screen, impingement can cause juveniles to roll over into the irrigation canal or may cause death if the fish cannot free itself from the screen surface. High approach velocities may also cause descaling/injury to fish, which may increase susceptibility to disease. Inappropriate patterns of sweep velocities (they should increase toward the bypass) may result in delays in passage.

Detailed information on these screen evaluations can be found on the web at http://www.pnl.gov/ecology/library/Screen/Screen.html.

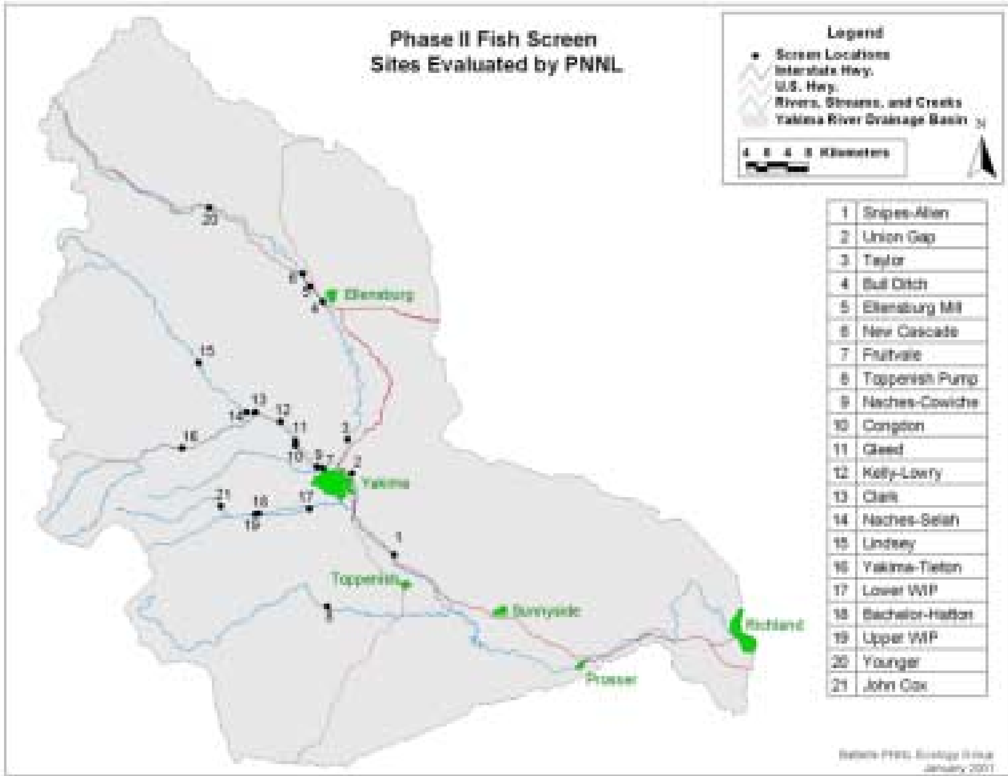


Figure 81. Phase II fish screen sites evaluated by PNNL.

Water Quality Conditions Near Proposed Fish Production Sites

In 1991, the Pacific Northwest National Laboratory (PNNL) studied water quality at several proposed Yakima Fisheries Project (YFP) fish culture sites in the Yakima River Basin (Dauble et al. 1994). The study found that the surface water quality parameters near the proposed sites were suitable for fish production. Water quality conditions in the upper part of the watershed (i.e., near Cle Elum) were generally excellent. Water quality of the Naches River near Oak Flats was also suitable for fish production. However, water quality in the Yakima River downstream of Union Gap (RM 107) was fair to poor.

Groundwater supplies near the proposed fish production facilities typically had elevated concentrations of metals and dissolved gasses. The authors reported that these conditions could be mitigated by employing best engineering practices such as precipitation and degasification. They also suggested that mixing surface and groundwater might improve those problems. Depending on the depth of the wells, the groundwater temperatures were found to be warmer than would be ideal for rearing/holding juvenile and adult salmonids. The authors suggested that chillers might be necessary at some sites during warm months. Quantities of water available were also judged to be insufficient for planned use at some sites (e.g., Oak Flats and Nelson Springs)—necessitating the drilling of additional wells to meet anticipated water requirements.

Water quality parameters measured in the Yakima River and tributaries sometimes exceeded the range of accepted values, however, constituent concentrations were within ranges that existed at many salmonid hatcheries in the Northwest. In addition, site-specific tests conducted by PNNL (i.e., live-box exposures and egg incubation studies) indicated that fish could successfully be reared in surface and well water near the proposed sites.

Physiological Assessment of Wild and Hatchery Juvenile Salmonids

The purpose of this research at the Resource Enhancement and Utilization Technology Division of the National Marine Fisheries Service is to evaluate supplementation and reduce negative impacts of hatchery salmon on wild salmon by improving the smolt quality and smolt-to-adult recovery (SAR) of hatchery-reared fish and by producing a more wild-type hatchery smolt in supplementation programs. High quality hatchery smolts are defined as fish with life-history attributes indistinguishable from related wild fish and are fish that migrate rapidly after release and survive to adulthood at relatively high rates. Rapid outmigration after release reduces time for hatchery fish to interact and compete with wild fish. Improving SAR of hatchery fish means that fewer juvenile hatchery releases will be needed.

After examining the physiology of wild Yakima River spring chinook from 1992 to 1997, researchers constructed a physiological template for naturally rearing Yakima River fish for future comparisons (Beckman et al., 2000). Significantly the wild fish study found a high growth rate of juveniles during smolting, which was similar to a finding from studies of successfully returning adult spring chinook salmon reared at production hatcheries (Dickhoff et al., 1995; Beckman et al., 1999). Researchers also examined the influence of growth rate on smolt physiology, instream survival and migration of Yakima spring chinook salmon and found high spring growth rate associated with rapid downstream movement (Beckman et al., 1998a,b).

From 1998 to the present, researchers— in collaboration with WDFW and the Yakama Nation—are collecting physiological samples from the first three generations of conventionally and semi-naturally reared hatchery fish at the Cle Elum Supplementation facility, at remote acclimation sites, and at downsteam sites during outmigration. The conventional raceways are characterized by gray concrete, no instream structure, and surface feeding whereas the semi-natural raceways are characterized by camouflaged walls, instream structure, and sub-surface feeding. Data are being compared with physiological profiles of naturally rearing Yakima River spring chinook to modify rearing protocls used in current and future supplementation projects.

Instream Flow and Ecological Function in the Yakima River Basin

A scientific study funded under the Yakima River Basin Water Enhancement Program is a review and synthesis of scientific data and information on instream flow as related to the ecological functioning of the Yakima River Basin. The purpose is to aid in identification of primary areas where changes in water management and flow alteration offer the greatest potential to recover and enhance the ecosystem. The draft final document was issued to the public in December 2000 and the final document will be completed by March 2001.

Minimizing Adverse Impacts to the Aquatic Environment

The U.S. Bureau of Reclamation is funding several studies to help understand how to minimize impacts to listed species and the aquatic ecosystem while operating the federal Yakima Project. Such studies include:

- Rimrock Reservoir Outlet Entrainment. This project is intended to estimate entrainment of fish from the Tieton Dam outlet structure. Entrained fish could include bull trout.
- Steelhead Habitat Use. Researchers are investigating the movement of steelhead above Roza Dam and associated habitat use in the Yakima River above Roza Dam. Biotelemetry will be used to track fish movements.

- Yakima Basin Bull Trout Studies. Reclamation funds studies to assess adult spawning populations at some of the reservoirs and migration to and from the reservoirs.
- Limnology of Five Reservoirs of the Upper Yakima Basin. Basic limnology surveys are being conducted in reservoirs where bull trout are found.
- Native Fishes Study. This is a study of the distribution and abundance of native fishes in the Yakima River blow Roza, Sunnyside and Prosser Dams.

Ecological Interactions—Yakima River Species Interaction Studies

Species interactions research was initiated in 1989 to investigate ecological interactions among fish in response to proposed supplementation of salmon and steelhead in the upper Yakima River basin. Data was collected primarily by the Washington Department of Fish and Wildlife (WDFW) between December 1989 and 1998. Currently, reports are being prepared for fieldwork conducted through December 2000. As data is accumulated it is compared to data from previous years to identify preliminary trends and patterns. The most definitive statements are found in the latest reports. All reports are cited in References and are available on the internet and can be identified by the title *Yakima River Species Interaction Studies*. Findings and recommendations are described in the reports. The methodologies used in baseline data collection, analyses and modeling are also described.

The first years of this research focused on the monitoring and collection of baseline data, including the use of electrofishing surveys in the tributaries and mainstem of the upper Yakima basin; spawning surveys on 13 tributaries and seven mainstem Yakima River areas; relative abundance surveys of all fish species in ten tributaries of the upper Yakima River; spawning surveys, population estimates, movement and growth of trout, and genetic identification of trout stock (Hindman et al 1991; McMichael et al. 1992; Pearsons et al. 1993). The data collected was used initially to characterize the rainbow trout population, predict the potential interactions that might occur as a result of supplementation, and develop methods to monitor interactions (Pearsons et al. 1994). Some of the major findings include:

- As a result of four successive annual experimental releases of approximately 33,000 hatchery steelhead into a tributary of the North Fork Teanaway River, no impacts to the sizes or densities of sympatric wild trout, or large scale displacements of trout were detected. However, agonistic interactions and small-scale displacements were observed between hatchery steelhead and wild rainbow trout, with hatchery steelhead behaviorally dominating presumably because of their larger size (Pearsons et al. 1994). Superior performance of hatchery-reared steelhead, reflected by more rapid in-river emigration rates, lower rates of precocialism, and lower incidence of residualism, was observed when parents were hatchery broodstock as opposed to wild broodstock. Performance was also enhanced when hatchery steelhead were reared at lower densities and released at smaller sizes.
- Researchers concluded that correlations between parentage and performance were consistent during the four-year study, but rearing density and size at release deviated from the general pattern in 1994 (Pearsons et al. 1996). The results of these experimental releases were used to develop a preliminary recommendation regarding the appropriate spatial and temporal scale necessary for monitoring ecological interactions and to provide strategies to minimize undesirable ecological interactions between hatchery and wild fish (Pearsons et al. 1994).

- Results from competition experiments performed in small screened enclosures within the North and Middle forks of the Teanaway River suggested that: 1) the presence of hatchery-reared steelhead negatively impacted growth of naturally produced rainbow trout, but did not impact the growth of spring chinook salmon; 2) the presence of hatchery-reared spring chinook salmon negatively impacted the growth of wild spring chinook salmon; and 3) the presence of wild spring chinook salmon did not impact the growth of wild rainbow trout. The potential impact of hatchery spring chinook salmon on wild rainbow trout was not examined (McMichael et al. 1997).

In 1995, the ecological interactions team began also to characterize the ecology and demographics of non-target taxa (NTT) and target taxon, predict the potential interactions that may occur as a result of supplementation, and develop methods to monitor interactions and supplementation success (Pearsons et al. 1998). Objectives for highly valued non-target taxa (NTT) were described as acceptable impacts to their current status that could be attributed to spring chinook salmon supplementation. Impacts to a NTT's distribution, abundance, or size structure in excess of the acceptable impact would indicate a failure to achieve an objective. The recommended NTT objectives are shown in Table 53. These objectives reflect the goal of having all native species at sustainable levels including populations robust enough to support harvest and recreation.

Table 54. Non-target taxa of concern objectives. (Pearson et al, 1998)

NTTOC	Containment Objective
Rare - species, stock, or regionally	no impact
Bull trout	
Westslope cutthroat trout	
Pacific Lamprey	
Naches steelhead	
Satus steelhead	
Toppenish steelhead	
Upper Yakima steelhead	
Rare - in basin	Very low impact ($\leq$ 5%)
Marion Drain Fall chinook	
Mountain sucker	
Leopard dace	
Sand roller	
Native game or food fish - very important	Low impact ($\leq$ 10%)
Resident rainbow trout in the mainstem Yakima River	
Naches spring chinook salmon	
American River spring chinook salmon	

Native game or food fish - important	Moderate impact (≤ 40%)
Mountain whitefish	
Resident rainbow trout in tributaries	
Common	≤ maximum impact that maintains all native species at sustainable levels
Other native species	

Proposed containment objectives for non-target taxa of concern (NTTOC) in the Yakima Basin relative to supplementing upper Yakima spring chinook salmon. Objectives refer to negative impacts upon one or more of a taxon distribution, abundance or size structure relative to pre-supplementation levels.

Other major findings and recommendations include:

- Certain species or guilds within an ecosystem may interact strongly with spring chinook salmon resulting in failure to achieve desired numerical goals of spring chinook salmon through supplementation. Monitoring the influence of strong interactor taxa relative to spring chinook salmon will aid in interpreting factors that may influence YFP success. Recommended objectives for strong interactors are of two types: 1) identify and reduce impacts of unnaturally high predatory, pathogenic, and competitive interactions that limit spring chinook salmon productivity, and 2) identify, conserve and enhance mutualism and prey taxa function at or above baseline levels to support maintenance or enhancement of ecosystem capacity for spring chinook salmon.
- In controlled experiments conducted in three small high elevation streams, juvenile spring chinook salmon did not impact the growth or abundance of age -0 or -1 rainbow trout. (McMichael and Pearsons 1998).
- Gene flow between resident and anadromous *Oncorhynchus mykiss* has occurred in the Yakima basin. Naturally produced rainbow trout were genetically indistinguishable from naturally produced steelhead when collected in sympatry. In addition, estimates of hatchery and wild fish admixtures in naturally produced *O. mykiss* indicated that hatchery rainbow trout had previously spawned with steelhead; and hatchery steelhead had previously spawned with rainbow trout.
- The maximum size of fall chinook salmon consumed by coho salmon smolts in laboratory trials was 74 mm and the largest relative size (fall chinook salmon length/coho salmon length) consumed was 46%. Initially (3 days; the approximate time it takes for actively migrating coho salmon smolts to exit the Yakima River), coho salmon consumed the smaller fall chinook salmon, generally less than 40% of the coho salmon's body length (Pearsons and Fritts 1998).
- Sufficiently large numbers of northern pikeminnow, smallmouth bass, and channel catfish were captured in the lower Yakima River to warrant the calculation of predation indices in future years. Northern pikeminnow and smallmouth bass had similar diets, with 23 to 29% of the stomachs of these species containing salmonids.
- Potential for adverse impacts resulting from ecological interactions among wild salmonids and hatchery steelhead was greatest when (1) hatchery fish did not emigrate quickly; (2) water temperatures were over 8° C; (3) hatchery fish were the same species as the wild salmonids; (4) hatchery fish were larger than the wild

salmonids; (5) habitat and/or food were limiting; and (6) numbers of fish released was over about 30,000 per stream. Ecological interactions with wild salmonids could be reduced or minimized by releasing; (1) only actively migrating smolts (no residuals); (2) hatchery fish of a size that minimizes interaction potential (smaller than wild fish); (3) the minimum number necessary to meet management objectives; (4) fish that do not exhibit counter-productive and inappropriate behaviors (e.g., less likely to engage wild fish in agonistic encounters); and (5) when water temperatures are relatively cold (less than 8^{o} C) (McMichael et al. 1999).

In 1998 species interaction research turned to issues associated with monitoring potential impacts to support adaptive management of NTT and baseline monitoring of fish predation indices on spring chinook salmon smolts (Pearsons et al. 1999). Researchers examined variability in abundance of 16 native fish taxa to determine if rapid, sensitive detection of change is possible for native fish populations in the Yakima River basin. Detectable impacts decreased with greater quantity and quality of baseline surveys, but high temporal variability prevented detection of small impacts for most taxa.

The ecological interactions team examined the potential to adaptively manage ecological impacts to wild fishes. Interactions monitored include predation and spatial overlap with target species. Monitoring options, alone or in combination, often failed to achieve adequate power to detect impacts equal to the containment objective (CO) for some or all interaction types. Inadequate feedback will prevent the adaptive management approach from assuring that ecological impacts to NTT that exceed the CO are quickly corrected. However, some NTT could be monitored well enough to facilitate risk containment management and monitoring will provide the potential of some risk containment for all of the NTT (Ham and Pearsons In Press, Ham and Pearsons Submitted).

During 1998, researchers calculated predation indices (PI) for the three primary fish predators in the lower Yakima River: smallmouth bass, northern pikeminnow, and channel catfish. By extrapolating smallmouth bass numbers from the mouth of the Yakima River upstream to Prosser Dam, researchers estimated that smallmouth bass could consume about 18,840 salmonid smolts/day in the lower 68 km of the Yakima River daily during the smolt emigration period. (Most of the smallmouth bass predation on salmonids was on fall chinook salmon parr and smolts.) Estimates of the number of salmonids consumed by northern pikeminnow above Prosser ranged from 35-390 salmonids/1000 predators/day throughout the emigration period. Researchers captured large numbers of channel catfish, and 2.9% of the stomachs examined contained at least one salmonid. One channel catfish contained 76 fall chinook salmon, and several other fish species in its gut. Predator control options are discussed, with the most promising being a 2 C decrease in water temperature in the lower Yakima River.

Ecological Interactions—Spring Chinook Salmon Interactions and Residual/Precocial Monitoring in the Upper Yakima Basin

Select ecological interactions and spring chinook salmon residual/precocial abundance were monitored in 1998 as part of the Yakima/Klickitat Fisheries Project’s supplementation monitoring program (James et al. 2000). The ecological interactions that were monitored were prey consumption, competition for food, and competition for space. Residuals and precocials, spring chinook salmon life history forms that have the potential to be influenced by supplementation and that have important ecological and genetic roles, were monitored. Residual spring chinook salmon do not migrate to the ocean during the normal emigration period and continue to rear in freshwater. Precocials are those salmon that complete their lifecycle in freshwater. The purpose of sampling during 1998 was to collect baseline data one year prior to the release of hatchery spring chinook salmon which occurred during the spring of 1999. All reported sampling was conducted in upper Yakima River during summer and fall 1998. Findings included:

- The stomach fullness of juvenile spring chinook salmon during the summer and fall averaged 12%. The food competition index suggested that mountain whitefish, rainbow trout, and redside shiner were competing for food with spring chinook salmon. The space competition index suggested that rainbow trout and redside shiner were competing for space with spring chinook salmon but mountain whitefish were not.
- Among potential competitors, age 1+ rainbow trout exhibited the greatest degree of microhabitat overlap with spring chinook salmon.
- Abundance of naturally occurring spring chinook salmon residuals (age 1+ during the summer) was low (< 0.007/m), representing less than 2% of the naturally produced spring chinook salmon (age 0+ and age 1+ during the summer). Abundance of naturally occurring spring chinook salmon that mature in freshwater was high relative to anadromous adults. We observed an average of 9.5 precocially mature spring chinook salmon on redds with anadromous adults. In addition, 87% of the redds with anadromous adults present also had precocial males attending.

Ecological Interactions—Development of Bird Predation Index

Avian predation on juvenile salmonids in the Yakima River was studied from fall 1997 to summer 1998 with emphasis on spring chinook rearing areas (Phinney et al. 2000). Index sections were established in free-flowing stretches to determine abundance of avian predators in each chinook rearing area. Predation “hot spots” were studied during spring to determine the impact of piscivorous birds on juvenile salmonids during outmigration. “Hot spots” are areas such as irrigation diversion dams and irrigation canal smolt bypass outfalls where fish become concentrated and disoriented. Finally, to determine which birds respond most readily to high concentrations of fish in different parts of the river, hatchery salmonid acclimation sites were studied.

Floats through index areas indicated that avian predation was low in the lower river during the spring smolt outmigration. Summer observations in the upper river suggested that common mergansers and their broods may consume large numbers of non-migrating chinook fry. Fall and winter observations suggested that mergansers were the major avian predator of rearing spring chinook.

Numerous hot spots were studied, but predation was highest at the Chandler Canal bypass outfall and at Horn Rapids Dam, both sites in the lower 50 km of the river. Assuming that all fish were consumed by gulls in proportion to their relative abundance, consumption at Chandler Canal bypass outfall was 174 (SE 33) spring chinook or 0.20% of the spring chinook that passed through the outfall during the study period. Under the same assumption, gull consumption at Horn Rapids Dam was 1316 (SE 143) spring chinook or 0.52% of the spring chinook that passed over the dam during the study period. There was a significant relationship between gull foraging and river flow such that at high flows, foraging was precluded.

The large concentrations of fish found at acclimation sites attracted avian predators. Gulls were the primary avian predator at an acclimation site in the lower Yakima River, great blue herons and common mergansers were the primary avian predators at an acclimation site in the middle Yakima River, and mergansers were the primary avian predator at an acclimation site in the upper Naches River. The merganser predation observed at the upper Naches River acclimation site suggests that mergansers will be the main avian predator at a newly started upper Yakima River hatchery designed to supplement the natural spring chinook salmon population.

Several options exist to reduce avian predation at the Chandler Canal bypass outfall and Horn Rapids Dam including redesign of the Chandler Canal bypass fish return pipe, erection of overhead lines, making three nearby the Columbia River islands unsuitable for nesting by planting dense vegetation and other means.

Under the higher than average spring flow conditions of 1998, avian predation does not appear to be a significant limiting factor of salmonid production in the Yakima River.

Yakima River Spring Chinook Enhancement Study

The natural production, and potential methods of enhancing, the Yakima River spring chinook salmon (*Oncorhynchus tschawytscha)* were studied by the Yakama Nation Fisheries Program from 1982 through 1990 (Fast et. al., 1991). Researchers studied naturally produced populations to determine if runs could be sustained. Survival through each life stage was evaluated to determine limitations to natural production.

From 1981 to 1990 the average run was 3,819 adults. The runs steadily increased from their respective brood years until 1988, when the Yakima River experience three years of declining returns.

The study determined that the Yakima subbasin was comprised of three distinct substocks of spring chinook—American River, Naches River and tributaries, and the upper Yakima River. Carcass data indicated that the American River were predominantly 5-year-old adults; the Naches River and tributaries was a combination of 4- and 5- year olds; and the upper Yakima consisted of mostly 4-year old adults.

A total of 14 redds were successfully capped and it was determined that egg to fry survival ranged from 21.9% to 90%, with a mean of 59.6%. Early juvenile rearing distribution generally corresponded to adult spawning area. Juveniles migrated into the lower reaches of the Yakima in the fall and winter months.

Spring smolt outmigration at Prosser dam ranged from 92,934 in 1989 to 282,514 fish in 1988 (mean = 177,561). Smolt outmigration was concentrated in April (mean 63%) and May (32%). Egg-to-smolt survival ranged from 1.3% to 10.6%. Regression analysis indicated that biotic density dependent or depensitory factors explained more annual variability than flow related parameters.

Smolt-to-adult survival for wild spring chinook salmon was based on estimated outmigration of smolts at Prosser dam from 1983 through 1987. The total number of adults returning from those outmigrations ranged from 4,209 to 8,596 adults (mean 5,655). Smolt-to-adult survival averaged 3.7% and ranged from 1.7% to 6.0%.

The major factors that limit spring chinook salmon rearing potential in the Yakima subbasin were determined to be suboptimal instream flows, passage around diversions, degraded riparian and instream habitat, and reduced water quality.

Supplementation experiments using hatchery-reared fish to enhance natural production were conducted. These experiments tested the manner of release (acclimation pond vs. direct river release), the time of release (fry in June, parr in September, and pre-smolts in November) and the brood stock used (progeny from wild by wild crosses – WxW, wild by hatchery – WxH, and hatchery by hatchery – HxH). Success was measured as post-release survival, as smolts to Prosser and adults back to the Yakima.

The acclimated smolts survived at a higher rate in three of the four years (about equal in the fourth year). The smolt to adult survival for acclimated fish was higher than survival of trucked fish in all four years. The studies of release timing had mixed results to the smolt stage with the September release being higher in 1984 (10.96% vs. 3.71%) and the November release exhibiting higher survival in 1985 (9.39% vs. 0.79%. The September releases did exhibit a survival advantage to the returning adult stage (0.08% vs. 0.05%). Too few of the June fry releases passed Prosser as smolts in the year following their release to analyze with statistical reliability. These releases had a mean survival to the adult stage of only 0.016% over the two years. The estimated survival to Prosser of the hatchery reared "wild" smolts was marginally higher than for the hybrid and hatchery brood stock produced smolts. The wild fish also returned as adults at a slightly higher rate than the hybrid group.

Washington Trout Phenotype and Hybridization Research

With funding from Bonneville Power Administration Washington Trout undertook a survey in 1998 to photo-document representative phenotypes of native redband rainbow and westslope cutthroat trout in the Yakima and Naches sub-basins, and to obtain non-lethal tissue samples for DNA analysis to detect the presence of hybridization between westslope cutthroat and rainbow and between westslope and non-native cutthroat (see Trotter et al. 1999).

Planning

Yakima County On-going Planning Activities

The County is currently updating the critical areas ordinance/atlas. Current and future flood planning efforts will include mapping of channel migration zones and avulsion hazard areas, which will be used to enhance our ability to keep floodplains in their natural conditions by preventing development in high hazard areas. Plans will also look for opportunities to restore floodplains and benefit fish and wildlife.

Yakima County Comprehensive Flood Hazard Management Plans

Currently the Yakima County Countywide Flood Control Zone District (FCZD) is preparing Comprehensive Flood Hazard Management Plans (CFHMPs) for the lower Naches River (Painted Rocks to Tieton River), the lower Yakima River (Union Gap to Granger) and the West Valley (Ahtanum and Wide Hollow Creeks). The Lower Yakima plan development is dependent on funding. All of these projects involve extensive coordination with the Yakama Nation. It is hoped that the Yakama Nation will co-manage the West Valley and Lower Yakima CFHMP projects.

Real-time Hydrologic Data Collection

Bureau of Reclamation has put in place an extensive real time hydrologic data collection and data storage system in the Yakima River basin that allows observation, monitoring, and analysis of the system. It enables Reclamation's Yakima Project Office to better meet the system demands. A Hydromet system of some 60 stations has been installed over a period of years to provide real-time data on a number of parameters such as precipitation, reservoir contents, streamflows, diversion, water temperature and turbidity. Some of these data are available on the Internet at: http://mac1.pn.usbr.gov/yakima/yakwebarcread.html.

Development of RiverWare for the Yakima Basin

The Watershed and River System management Program is sponsored by the Bureau of Reclamation's Science and Technology Research Program and the U.S. Geological Survey's Water Resource Division. This program provides a data centered framework for water resources decision making. Today's complex resources management issues require flexible, comprehensive decision support tools that display timely information to water managers. As a part of the program, the Bureau of Reclamation is developing a RiverWare model specific to the Yakima Basin. Riverware is a generalized river basin modeling environment which integrates the multipurposes of reservoir systems, such as flood control, fish and wildlife needs, navigation, recreation, water supply, and water quality, with power system economics. Hence Riverware provides a river basin manager with a tool for scheduling, forecasting and planning reservoir operations to best meet multiple demands.

Collection of Accurate Elevation Data for Use with RiverWare

Light detection and ranging (LIDAR) and color infra-red (CIR) orthophotography will be used to acquire orthophotography and contour elevation data for several areas of interest surrounding and downstream from Bureau of Reclamation facilities along the Yakima and Naches Rivers. Elevation data points collected should have a horizontal position accuracy of 1-meter, or better, and a vertical position accuracy of 20 centimeters, or better. The resulting data will be used in conjunction with hydrologic modeling efforts to better manage water resources, including to reduce operations impacts on for fish and wildlife.

Yakima River Basin Water Enhancement Planning

The Conservation Advisory Group completed its task of producing water conservation guidelines for the Water Conservation Plan, which sets forth the mechanism for implementing water conservation measure in the Yakima river basin. Presently, six water conservation plans are under development.

The Interim Operating Plan group, comprised of members from state and Federal agencies, tribal representative, irrigation districts and environmental groups, was established to address issues concerning future operations of the Yakima River system within the basin. The group will make recommended actions about future operations and Reclamation will complete its plan in FY 2001. BPA is represented on the Interim Operating Plan group.

Following consultation with the State of Washington, tributary water right owners, and the Yakama Nation, a study will be conducted on non-storage items that can be implemented to enhance water supplies for fish and wildlife and irrigation in Taneum Creek. Reclamation seeks to partner with the Yakama Nation on a Taneum Creek steelhead supplementation effort. Other tributaries will be addressed as funding allows.

Present Subbasin Management

Existing Management

Federal, tribal, state and its local subdivisions own, manage and regulate land and water in the Yakima subbasin. Most entities have plans or policies and guidelines pertaining to the protection of water, land, fish and wildlife. Many of the numerous laws that underpin existing management, regulation and plans are described below along with the management entities.

International

United States-Canada Pacific Salmon Treaty

The Pacific Salmon Treaty is negotiated among Washington, Oregon, Alaska, tribes and the federal governments of the US and Canada. These discussions impact salmon stocks and harvest in the Yakima basin and throughout Washington.

Federal Government

Bureau of Reclamation

The U.S. Bureau of Reclamation (Reclamation) manages the federal Yakima Project, which is located within the subbasin. The Yakima Project provides irrigation water for approximately 465,000 acres of irrigable land that extend along both sides of the Yakima River. Reclamation operates the dam and reservoir system for project purposes such as: irrigation water supply, instream flows for fish, and flood control. Reclamation operates its dam and reservoir system in accordance with Federal and State Court orders governing water rights and entitlements. Chief among these is the 1945 Consent Decree. Reclamation operates its system in such a way as to protect Indian trust assets. Reclamation also operates in accordance with the decisions of the State Superior Court hearing the Acquavella adjudication, which has jurisdiction over water rights in the Yakima River Basin. Except for minor diversions and adjudicated minor streams, Reclamation limits diversions to quantities provided by:

I. The Limiting Agreements (1905-1913) signed by over 50 appropriators of natural flows
II. Water delivery contracts between the United States and water user entities
III. Provisions of the 1945 Consent Decree
IV. Acquavella Rulings.

The Yakima River Basin Water Enhancement Program, authorized in 1994, is a multi-faceted program intended, in part, to demonstrate water conservation techniques and enhance the fishery of the Yakima River basin by working with state and federal natural resource agencies and other interested groups. The Washington Department of Ecology assists with funding the four phases of the Basin Conservation Program. Other partners include the Yakama Nation, Bonneville Power Administration, Natural Resources Conservation Service, and others. The irrigation districts have been primary participants in nearly all of the activities.

Reclamation has initiated formal consultation under the Endangered Species Act with the National Marine Fisheries Service and Fish and Wildlife Service for operation and maintenance of the Yakima Project.

Environmental Protection Agency

The Environmental Protection Agency (EPA) and Washington Department of Ecology are responsible for carrying out the Clean Water Act. The EPA helps determine which lakes, estuaries and streams in the state fall short of state water quality standards. Impaired water bodies became part of the section 303(d) list under the act. The EPA requires the state to set priorities for cleaning up threatened waters and to establish plans for the allowable Total Maximum Daily Load (TMDL) of pollution a body of water can sustain and still be healthy.

Fish and Wildlife Service

The United States Fish and Wildlife Service (USFWS) is one of the principal federal agencies involved in the conservation, protection and enhancement of fish, wildlife, plants and their habitats. The agency's activities include management of migratory bird species, habitat restoration, fish passage and production, and management of national wildlife refuges. USFW holds primary federal management responsibility for non-anadromous fish, and share federal responsibility for anadromous fish resources. The USFW Endangered Species program is responsible for plant, wildlife and non-anadromous fish Endangered Species Act listings. The 1,763 acre Toppenish National Wildlife Refuge is located on Toppenish Creek within the Yakama Reservation.

National Forest Service

The Naches and Cle Elum Ranger Districts of the Okanogan and Wenatchee National Forests are responsible for managing about 500,000 acres and 375,530acres of land within the Yakima basin, respectively. These lands are primarily managed under provisions of the Wenatchee National Forest Land and Resource Management Plan of 1990 as amended by the Final Supplemental Environmental Impact Statement on Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl (1994). Other plans, policies and regulations which guide the management activities of the Naches and Cle Elum Ranger District are the 1973 Endangered Species Act, the 1977 Clean Water Act, PACFISH (1995) and the most recent watershed assessment available for each of the drainages under these Districts' management authority. For resources managed by the Cle Elum Ranger District, the Snoqualmie Pass Adaptive Management Area Plan (1997) also provides for the conscious integration of ecological process and social and economic values. The Assessments for Late Successional Reserves (LSR) and Managed Late Successional Areas (1997) include management guidelines for Manastash Ridge LSR (Cle Elum and Naches Ranger Districts), Swauk LSR (Cle Elum District within the Yakima Basin) and Teanaway LSR (Cle Elum Ranger District).

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS), a federal agency within the U.S. Department of Agriculture (USDA), works in cooperation with the Washington Conservation Commission and aids conservation districts in the three counties that make up the Yakima subbasin. NRCS manages a variety of programs that provide financial and technical assistance to implement conservation practices on privately owned land. Using this help, farmers and ranchers apply practices that reduce soil erosion and improve water quality; enhance forest and grazing land and wildlife habitat; and maintain riparian areas along streams containing salmonids fish.

National Marine Fisheries Service

The National Marine Fisheries Service (NMFS), an agency within the Department of Commerce, is responsible for implementing federal regulations pursuant to the Mitchell, Magnusun-Stevens, Federal Power, and Endangered Species Acts. NMFS consults with Federal agencies to ensure that their actions are sufficiently protective of anadromous fishes and their habitat. Notably, in the Yakima Basin, NMFS is responsible for enforcing the provisions of the Endangered Species Act (ESA) with respect to Middle Columbia River summer steelhead. Other ESA related activities include the development of recovery plans, negotiation of habitat conservation plans and the development of take limitation rules under section 4(d) of the ESA. NMFS also provides technical assistance in the design and construction f fish passage structures.

Yakima Training Center

The United States Department of the Army owns and occupies 323,651 acres in the Yakima subbasin. Acquired in 1942, the Yakima Training Center is bounded by I 82 on the east, the Columbia River to the west, Boylston Mountains to the north and the Yakima Ridge to the south. The Army continues to use the training center, which is managed by Fort Lewis, for state-of-the-art live fire training for infantry, tanks and, nowadays, helicopters. In addition to springs and numerous streams, including Selah Creek, the area is one of the largest remaining shrub-steppe habitats in Washington, with 27 plant, 37 wildlife and 2 fish species listed as sensitive by the state. The training center must comply with the Endangered Species Act, the Clean Water Act and other federal laws. Erosion, water pollution, denuded vegetation and compacted soil are a few of the problems the training center is attempting to tackle with its Integrated Area 5-Year Management Plan that was adopted in 1998. Some of the anticipated projects included reseeding, road realignments and closures and stream crossing improvements.

Tribes

Yakama Nation

The Yakama Nation, also known as the Confederated Tribes and Bands of the Yakama Indian Nation, is a fish and wildlife co-manager of the Yakima subbasin. The Yakama Nation is responsible for protecting and enhancing treaty fish, wildlife and other natural resources for present and future generations.

The 14 tribes and bands that compose the Yakama Nation ceded over 10 million acres, including the Yakima basin, in the June 9, 1855 treaty with the United States. Today the tribe's reservation is 1.2 million acres, most of it within the Yakima basin. The reservation and ceded lands still contain the traditional natural resources upon which the Yakama people depend for subsistence and spiritual and cultural sustenance. They are many and include salmon, deer, elk, huckleberries, cous (scientific name) and other roots and medicinal plants and the most sacred, water. In the treaty, the tribe reserved rights and responsibilities involving these resources. The treaty's Article 3 states:

> The exclusive right of taking fish in all the streams, where running through or bordering said reservation, is further secured to said confederated bands and tribes of Indians, as also the right of taking fish at all usual and accustomed places, in common with the citizens of the Territory, and of erecting temporary buildings for curing them; together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle upon open and unclaimed land.

As a result of these treaty-reserved rights, the tribe retains substantial governmental authority over activities that affect hunting and fishing. In the 1969 *Sohappy v. Smith /U.S. v. Oregon* decision and the 1974 *U.S. v. Washington* or Boldt decision, the federal courts reaffirmed treaty provisions. These decisions entitle the tribe to one half of the harvestable fish that pass through usual and accustomed tribal fishing grounds. *U.S. v. Washington* rulings include hatchery-bred fish as part of the harvestable population, and provide for the protection of the fishery from environmental degradation. The court-ordered *U.S. v. Oregon Columbia River Management Plan* sets harvest, escapement, and production goals pertaining to Indian and non-Indian allocation of anadromous fish resources.

The Yakima Nation tribal government enacts fishing, hunting and other regulations affecting its members under provisions of the Yakima Indian Nation Law and Order Code. Within the reservation, the tribe also manages timber, agricultural and recreational resources. The Yakama Nation provides upland bird hunting and rainbow trout and other fishing opportunities for reservation visitors. Within the subbasin, the Yakama Nation reviews proposed management on public lands, makes recommendations for fish and wildlife protection, and establishes and monitors livestock grazing leases on tribal allotments.

Based on tribal culture and sovereignty as well as science, *Wy-Kan-Ush-Mi Wa-Kish-Wit: Spirit of the Salmon* (CRITFC1995) makes institutional and technical recommendations for Columbia Basin salmon restoration and presents a Yakima subbasin plan, which calls for instream flow restoration, enforcement of water quality standards and supplementation of threatened salmon runs to harvestable levels, among other measures.

State Government

State of Washington

Washington's salmon restoration efforts are carried out on an inter-agency basis and coordinated by the Governor's Salmon Recovery Office. The *Statewide Strategy to Recover Salmon* was released in 1999, following legislation in 1998 enacting the Salmon Recovery Planning Act, the Watershed Planning Act and the Salmon Recovery Funding Act. The Strategy was designed as the state's long-term vision or guide "to restore salmon, steelhead, and trout populations to healthy and harvestable levels and improve the habitats on which fish rely."

The Salmon Recovery Planning Act provides the framework for developing restoration projects. It requires a limiting factors analysis and establishes a funding program for local habitat restoration projects. As a result of this act, an Independent Scientific Panel was created to provide scientific review of salmon recovery projects.

The Watershed Planning Act encourages voluntary planning by local governments, citizens, and tribes for water supply and use, water quality, and habitat at the Water Resource Inventory Area (WRIA) level. Grants are available to conduct assessments of water resources and develop goals and objectives for future water management.

The Salmon Recovery Funding Act established the Salmon Recovery Funding Board (SRFB) Lead Entity organizations to localize salmon recovery. The City of Selha, Selah, Yakima County and Yakama Nation formed the Lead Entity in parts of WRIAs 37, 38, and 39 in the Yakima subbasin. The SRFB makes decisions about funding for projects based on a science-driven, competitive process.

Key state laws dealing with land and water use and development include the Environmental Policy Act, Shoreline Management Act, growth Management Act, Floodplain Management Act, Forest Practices Act, Water Pollution Control Act, Hydraulic Project Approval Act, Aquatic Lands Act, Water Code and Water Resources Act.

Washington Conservation Commission

The Washington Conservation Commission (WCC) assists and guides local conservation districts. Washington State Conservation Commission manages the Salmon Habitat Limiting Factors Program. The program identifies specific problems limiting the success of salmon as the first step in restoring healthy salmon runs. The limiting habitat factors for salmonids will be identified for the Yakima subbasin in WRIAs 37, 38, and 39.

Administered by WCC, the USDA's Conservation Reserve Enhancement Program provides technical and financial assistance to qualifying landowners to install and maintain streamside buffers along waters that are spawning areas for salmon and steelhead stocks. The Conservation Reserve Enhancement Program fits into the Governor's Salmon Recovery Plan by fulfilling the habitat portion of the program for agricultural land. The Commission makes a variety of water quality grants to conservation districts.

Washington Department of Natural Resources

The Washington Department of Natural Resources is responsible for managing state forest resources, including fire prevention and suppression and administers the state's Natural Areas Program (NAP).

Washington Department of Fish and Wildlife

The mission of the Washington Department of Fish and Wildlife (WDFW) is to provide sound stewardship of fish and wildlife resources. WDFW is responsible for preserving, protecting, restoring and enhancing fin fish, shellfish, wildlife populations and their critical habitats. The agency strives to maximize fishing, hunting and non-consumptive recreational opportunities compatible with healthy, diverse fish and wildlife populations. The WDFW and treaty Indian tribes co-manage the state's salmon populations and are joining with the National Marine Fisheries Service and U.S. Fish and Wildlife Service to define recovery goals for listed species. The Yakima subbasin lies within the agency's south-central district.

A few of the important policies, plans and guidelines that drive WDFW management in the Yakima subbasin include: A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington (1984), 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI) (1993), 1992 Washington State Salmon and Steelhead Stock Inventory: Appendix Three, Columbia River Stocks (1993), Wild Stock Restoration Initiative (1993) Draft Steelhead Management Plan (1994), Wild Salmonid Policy (1997), Salmon Recovery Planning Act (1998), Watershed Planning Act (1998), and Salmon Recovery Funding Act (1998), Statewide Strategy to Recover Salmon - Extinction Is Not An Option (1999), Bull Trout and Dolly Varden Management Plan (SaSI, 2000). The court-ordered *U.S. v. Oregon Columbia River Management Plan* sets harvest, escapement, and production goals pertaining to Indian and non-Indian allocation of anadromous fish resources.

The Salmon and Steelhead Inventory and Assessment Program (SSHIAP) is an integral part of the Wild Stock Restoration Initiative and complements SASSI. It is a partnership-based information system that characterizes freshwater and estuary habitat conditions and distribution of salmonid stocks in Washington at the 1:24,000 scale. SSHIAP is designed to support regulatory, conservation, and analysis efforts such as Washington State Watershed Analysis, State Salmon Recovery, Habitat Conservation Planning, Ecosystem Diagnosis and Treatment (EDT), and others.

Through its Priority Habitats and Species Program, WDFW also provides important fish, wildlife, and habitat information to local governments, state and federal agencies, private landowners and consultants, and tribal biologists for land use planning purposes. PHS information indicates which species and habitat types are priorities for management and conservation; where these habitats and species are located; and what should be done to protect these resources.

In cooperation with Washington Ecology and Transportation departments and representatives from NMFS and USFWS, WDFW is developing consistent, science-based guidelines for habitat protection and restoration as part of the Salmonid Habitat Protection and Restoration Project (http://www.wa.gov/wdfw/hab/salguide/salguide.htm). These guiding principles encapsulate current assumptions about how ecosystems work, describe the preferred approaches for habitat protection and proper functioning and highlight the most important natural processes for habitat preservation.

Washington Department of Ecology

The mission of the Department of Ecology (WDOE) is to protect, preserve and enhance Washington's environment, and promote the wise management of our air, land and water for the benefit of current and future generations. It goals are to prevent pollution, clean up pollution and support sustainable communities and natural resources. WDOE is responsible for implementing the federal Clean Water Act and enforcing the water quality standards. In accordance with Section 303(d) of the act, every two years the state must identify its polluted water bodies and what type of pollution they suffer from and submit this list to EPA. In 2000 over 50 sections of streams and rivers in the Yakima subbasin were listed as impaired under 303(d). WDOE also administers the Watershed Planning Act. The Tri-County Water Resource Agency is conducting watershed planning for the Yakima subbasin under a WDOE grant.

Interagency Committee for Outdoor Recreation

The Interagency Committee for Outdoor Recreation's (IACOR) mission is to provide quality service to its boards and the public while providing for recreation opportunities and protection of fish and wildlife. One of the boards administered by the IACOR is the Salmon Recovery Funding Board which supports salmon recovery through funding habitat protection and restoration projects, and related programs and activities that produce sustainable and measurable benefit for the fish and their habitat. Local governments, private landowners, conservation districts, Native American tribes, non-profit organizations, special purpose districts and state agencies are eligible to receive funding through the Salmon Recovery Funding Board grant programs. A number of habitat protection and restoration projects in the Yakima River Subbasin are funded through the Salmon Recovery Funding Board.

Conservation Districts

Conservation Districts are extensions of state government established to cooperate with the National Resource Conservation Service field offices and provide direction on local resource issues. A Board of Supervisors consisting of local landowners directs each conservation district. The goal of a conservation district is to provide leadership, technical and financial assistance to protect and improve natural resources in each district. In the Yakima River Basin, the Conservation Districts are Kittitas County Conservation District, North Yakima Conservation District, South Yakima Conservation District and Benton Conservation District.

Local Government

Tri-County Water Resources Agency

The mission of the Tri-County Water Resource Agency, based in Yakima, Washington, is to promote the responsible management of water resources today to protect and preserve water for the future. The agency stresses locally formulated plans for adequate water for domestic use, industry, agriculture and fisheries and attempts to coordinate with all water interests, including the Yakama Nation and federal and state initiatives and programs. In 1999 the Tri-

County Water Resource Agency began a large and important undertaking: The agency is providing the leadership, management and administrative support for the preparation and implementation of a comprehensive water plan for the Yakima River Basin. Through an intergovernmental agreement, local governments, irrigation districts and Kittitas, Yakima and Benton counties are working together to develop the Comprehensive Yakima River Basin Watershed Management Plan under the authority of the Watershed Management Act (Chapter 90.82 RCW), also known as HB 2514. The area covered is designated as Washington Resource Inventory Areas (WRIAs) 37, 38, 39. One of the first phases of this project, the Yakima Basin Watershed Assessment, was completed in June 2000. It covers water quantity, water quality and habitat in the basin. The next phase is the actual planning effort, and it began in January 2001. Washington Department of Ecology funds this project.

Yakima County

Within Yakima County there are approximately nine major creeks or rivers along with numerous tributaries and minor or intermittent streams. The length of some of these which fall under the jurisdiction of Yakima County include:

Major Water Body	Approximate Miles of Floodplain
Yakima River	57 (shared w/Yakama Nation)
Wenas Creek	24
Naches River	33
Tieton River	12
Cowiche Creek	20
Wide Hollow Creek	35
Ahtanum Creek	40 (shared w/Yakama Nation)
Toppenish Creek	Primarily Yakama Nation Jurisdiction
Status Creek	Yakama Nation Jurisdiction

*Doesn't include areas where County has overlapping Jurisdiction with State and Federal Agencies

The Yakima County Surface Water Management Program (SWMP), which includes the Countywide Flood Control Zone District (FCZD), is charged with developing resource management plans that are currently implemented by other County departments (Planning Department, Permit Services Division, Road Maintenance Program).

The Surface Water Management Program is primarily focused on Public Works activities related to surface waters, with the goal being to accommodate the Endangered Species Act (ESA), the National Pollutant Discharge Elimination System (NPDES) Phase II stormwater regulations, and the development of Total Maximum Daily Loads (TMDLs) for creeks and rivers within the County. The Countywide FCZD provides guidance and planning to the County related to floodplain development proposals and comprehensive multi-objective floodplain management.

The authority to conduct management activities is based mainly on the County Critical Areas Ordinance, Shoreline Master Program, Flood Hazard Ordinance, Grading Ordinance, and Building Permit System. Additional ordinances will be required to comply with emerging state and federal regulations. The Current Critical Areas Ordinance was made effective in 1995 and is being updated.

The FCZD is responsible for preparing Comprehensive Flood Hazard Management Plans (CFHMP). A CFHMP has been completed and adopted for the Upper Yakima River (Selah Gap to Union Gap). Once a CFHMP is adopted, it is currently up to the Planning Department and Permit Services to implement them with the assistance of the FCZD.

City of Yakima

The City of Yakima is centrally located in the middle of the Yakima Basin, in the Ahtanum-Moxee subbasin at the confluence of the Yakima and Naches River. Yakima is the largest population center in the subbasin. The City of Yakima operates a diversion dam on the Naches River to supply water to its water treatment plant. It also maintains two water delivery systems; one for potable water and one for irrigation water. The City's irrigation utility currently serves approximately 10,690 parcels, totaling over 2,000 irrigated acres. The Irrigation Utility in the City is served partially by City-owned water rights and supplemented by water shares from several local canal companies, Yakima-Tieton Canal Company, Naches and Cowiche Canal Company, Yakima Valley Canal Company, RS&C Irrigation Company, New Schanno Ditch Company, Broadgage Ditch Company and Old Union Ditch Company.

The City of Yakima has a strong Wastewater Management Plan which prevents the unauthorized discharge to the municipal wastewater system and is consistent with the Environmental Protection Agency Cleanwater Act. In addition, the City has a Critical Area Zoning and Building Code Ordinance that prevents construction within wetlands and establishes a riparian zone setback of 200 feet for class AA streams and 100 feet for class A streams. A Master Irrigation Plan was finalized in January of 2000, and a Stormwater Management Plan is currently under development.

The City is developing and implementing a comprehensive water resources management approach that includes domestic and irrigation water supply, waste water treatment, surface water diversion structure improvements, and other components. This work is being conducted within the context of the regulatory considerations of Growth Management Act, the Endangered Species Act, and the Clean Water Act, among others. The comprehensive water resources plan also takes into account the City's responsibility for environmental stewardship and its responsibility to the citizens of the City of Yakima and associated service area and the Yakima Basin community.

Roza-Sunnyside Board of Joint Control (RSBOJC)

The Roza-Sunnyside Board of Joint Control was formed in 1997, and is a cooperative agreement between two lower valley irrigation districts (the Roza and Sunnyside Irrigation Districts) with the purpose of conserving water and monitoring and improving water quality of return flows. The RSBOJC has established water quality objectives to meet the TMDL goals that have been set for the lower Yakima River. The RSBOJC is also measuring several water quality parameters to establish the effectiveness of water conservation and water quality improvement projects.

Other

Timber Fish and Wildlife Agreement

In 1987, the Washington timber industry, tribes and tribal organizations, state and local governments, recreational and environmental groups began implementing the

Timber/Fish/Wildlife (TFW) Agreement. This Agreement established a cooperative forum to address forest practices on state and private lands in the state of Washington to provide protection for fish, wildlife and water quality, while providing long-term stability for the timber industry. Products of the TFW Agreement have included new administrative forest practices rule adopted by the State of Washington that provide stream-side protection through riparian management regulations, on-site evaluation of forest practices by interdisciplinary teams, watershed basin planning, monitoring procedures and wetland protection and watershed analysis rules. Key components of the TFW Agreement process are its consensus-based approach to decision-making and its use of adaptive management.

Agriculture, Fish and Water (AFW) Process

In 2000, a coalition of farmers, irrigation districts, environmental groups, state, federal and local government agencies, tribal governments, and legislators joined in a collaborative effort to address fish recovery and pollution control on farmlands. The AFW effort is part of the Governor's Salmon Recovery Plan, and consists of two concurrent processes: the Field Office Technical Guide (FOTG) process and Irrigation Districts' Guideline Development process.

The FOTG process involves negotiating changes to existing farm conservation practice standards. Issues covered by this process include water quality and fish habitat issues such as bank stability, "properly functioning conditions" that fish need for survival, and management of riparian zones. New or revised FOTGs would then be used to develop farm plans that provide regulatory certainty when implemented.

The second component to AFW includes the irrigation districts working with participating AFW members to develop guidelines that will address water use and conservation and water quality requirements. These new guidelines would be sued by irrigation districts to prepare Comprehensive Irrigation District Management Plans to help enhance, restore, and protect habitat for endangered fish and wildlife species, and address state water quality needs.

The Nature Conservancy

The Nature Conservancy is a private non-profit organization committed to preserving plants, animals, and natural communities that represent the diversity of life by protecting the lands and waters they need to survive. The Washington Nature Conservancy established its Yakima River Canyon preserve in 1993 to protect this unique habitat. The preserve includes 106 acres of basalt cliff habitat in the Yakima River canyon, as well as important grasslands and an island in the middle of the Yakima river. The Conservancy also owns 10 acres of bog habitat in the Moxee area to protect the silver-bordered fritillary. Additionally, the Nature Conservancy has worked with other agencies in the subbasin to form cooperative agreements for the protection and management of habitats in the Union Gap and Teanaway areas

Tapteal Greenway

Tapteal Greenway is a non-profit organization concerned with the Tapteal green corridor and trail along the Yakima River from Benton City (Kiona Bridge at RM 29.9) to the mouth of the river. Members are involved with habitat stewardship, land conservation and environmental education activities. Habitat stewardship and land conservation activities including trail maintenance, clean-ups, water quality monitoring, and restoration, land purchase and bank stabilization demonstration projects. Environmental education include in-school and public outreach programs on salmonids, water resources issues, riparian and shrub-steppe habitats and wildlife important to the area.

Washington Trout

Washington Trout is a nonprofit conservation ecology organization established in 1989 whose mission is to preserve, protect, and restore Washington's wild fish and their habitats. In the Yakima Basin, Washington Trout works to help attain the preservation of native resident and anadromous fish populations and their habitats and to recover normative ecosystem conditions as the surest way to secure the recovery of diverse and abundant wild salmon and steelhead populations.

Recent activities in the Yakima Basin include regular attendance at System Operations Advisory Committee (SOAC) meetings, providing input on biological issues pertaining to flow management, and written comment upon drafts of SOAC's report to Congress on Biologically Based Flows under Title XII legislation. Washington Trout has articulated concerns to local Yakima Basin agencies and state agencies regarding the deleterious ecological impacts of floodplain gravel mining operations and participated in a legal challenge to the proposed expansion of Central Pre-Mix's Selah Pit. Participating in the annual peer review (PAR) of the Yakima Fisheries Project is a component of Washington Trout's region-wide monitoring and evaluation of artificial production and its impacts on wild salmonid populations and ecosystems.

Existing Goals, Objectives, and Strategies

The following section summarizes existing fish and wildlife goals, objectives and strategies for the Yakima subbasin. The overall goal is to protect, restore and enhance fish and wildlife and their habitats in the Yakima subbasin to provide ecological, cultural, economic and recreational benefits.

Goal 1. Maintain and protect existing high quality habitat areas and the native populations inhabiting those areas.

Objective 1 Maintain reaches and upland areas in good condition as, as identified in "Habitat Areas and Quality."

- Strategy 1 Purchase lands with key habitat components, including refuge reaches, such as floodplain and side channel habitat. Numerous sites have been identified by NMFS, Yakama Nation, WDFW, and many other organizations.
- Strategy 2 Develop conservation easements or other incentives to encourage landowners to use management practices beneficial to fish and wildlife.
- Strategy 3 Yakima County use of Comprehensive Flood Hazard Management Projects(CFHMP) to for preservation and restoration of floodplains.
- Strategy 4 Enforce and apply state and federal environmental regulations.
- Strategy 5 Practice ecosystem and biodiversity management.
- Strategy 6 Implement WDFW Salmon and Steelhead Inventory and Assessment Program (SSHIAP).
- Strategy 7 Form partnerships, and participate at all levels of government to assess and maintain quality fish and wildlife habitat.

Objective 2 Reduce and prevent future anthropogenic impacts from riparian and wetland development, roads, agriculture and forestry

Strategy 1 Discourage development in floodplains (CFHMP).
Strategy 2 Relocate auto wrecking yards from floodplains and restore sites for fish and wildlife habitat.
Strategy 3 Enforce and apply state and federal environmental regulations on floodplain development.
Strategy 4 Practice ecosystem and biodiversity management.
Strategy 5 Protect listed species under Endangered Species Act.

Objective 3 Maintain and restore habitat for all salmon and steelhead throughout their historic range.
Strategy 1 Use Ecosystem and Diagnosis Treatment (EDT) Model to determine and prioritize critical reaches for Protection and Restoration for benefit to salmon and steelhead.
Strategy 2 Identified habitat necessary for sustaining critical life history stages of all historic salmon and steelhead will be protected or restored.

Objective 4 Maintain and restore stock distribution of native char (bull trout) and their habitat throughout their historic range.
Strategy 1 Habitat necessary for sustaining critical life history stages of native char including spawning and rearing will be protected or restored. WDFW will continue work with USFS and DNR to reduce cattle grazing impacts on Ahtanum and S. F. Tieton watersheds.
Strategy 2 WDFW will work to protect current migratory corridors connecting remote headwater areas and restore historical migration corridors. WDFW has and will work with BOR during low water years to assure passage of bull trout from Kachess Lake to Box Canyon Creek.

Objective 5 Continue mapping and collecting habitat information on Yakima watershed.
Strategy 1 Evaluate and implement various aerial mapping methodologies (FLIR, LIDAR, and others) to collect and map habitat information for use in documenting and monitoring watershed and habitat conditions in the Yakima Subbasin.
Strategy 2 Use GIS map technology to record historical fish, wildlife, and habitat conditions for the Yakima Subbasin.

Objective 6 Map and periodically monitor specific types of shrubsteppe and non-federal forest habitat within the Yakima subbasin.
Strategy 1 Map all habitat within the subbasin using a method that permits evaluation of habitat potential, habitat condition, and endemic features of the landscape such as slope, aspect, soil, and weather by the year 2005.
Strategy 2 Develop a system for monitoring changes in habitat on a regular 5- year interval by the year 2005.

Objective 7 Secure key habitats through purchase, conservation easement, lease or other appropriate means (Meuth 1989, Parker 1989, Bich et. Al 1991, Ratti and Kadlec 1992, YN 1994, WDFW State Recovery Plan for Ferruginous Hawk, 1996, Hays et al 1999, WDFW 2001)

Strategy 1 Protect an additional ³16,000 ha. of high quality, occupied, relatively contiguous habitat throughout Management Zones 1, 3, 5, and 6 [Yakima Subbasin is recovery Zone 6] (WDFW State Management Plan for Sage Grouse, 1995).

Strategy 2 Secure 27,000 acres of floodplain habitats on the Yakama Reservation (Bich et al 1991, YN 1994)

Strategy 3 Acquire approximately 10,000 acres of inholdings on Wenas, LT Murray, Sunnyside and other wildlife areas (WDFW 1994 – LT Murray Mgt Plan)

Strategy 4 Secure approximately 20,000 acres of key deer and elk winter range in the Yakima sub-basin (WDFW 2001).

Strategy 5 Acquire or protect wetland and riparian habitats (Meuth 1989, Parker 1989, Bich et. al 1991, Ratti and Kadlec 1992, YN 1994, YN 2001, Nordstrom and Milner 1997, Hays et al 1999, Knutson and Leaf 1997)

Strategy 6 Acquire or protect remaining old growth dry forest stands, particularly ponderosa pine. (USDA/USDI ICBEMP 1997)

Objective 8 Enforce existing policies, laws and guidelines designed to protect and maintain habitats.

Goal 2. Restore degraded areas, and return natural ecosystem functions to the subbasin.

Objective 1 Increase flows in specific sections of the basin especially during times when anadromous fish are present

Strategy 1 Investigate the feasibility of moving the intake system for Kennewick Irrigation District from the Yakima River to the Columbia River (Kennewick Pump Exchange)

Strategy 2 Investigate buying out the Wapatox Power Plant to increase instream flows in the Naches River Strategy 3 Increase instream flows in the Teanaway River through irrigation systems that conserve water and other means

Strategy 4 Protect listed species under the Endangered Species Act

Strategy 5 Investigate increasing flow in lower Yakima River to decrease temperature and improve smolt and adult salmon survival.

Strategy 6 Implement WDFW Salmon and Steelhead Inventory and Assessment Program (SSHIAP)

Objective 2 Maintain and restore habitat necessary for sustaining critical life history stages including spawning, rearing and migration.

Strategy 1 WDFW, consistent with its authority of the State Hydraulic Code will incorporate conditions into Hydraulic Project Approvals (HPAs) to protect salmonids, native char (bull trout) and other native fishes.

Strategy 2 WDFW will provide input into State Environmental Policy Act review documents, forest practice applications, the TFW process and the Forestry Module, growth management plans, mitigation agreements and water rights applications to protect fish habitat, including for native char (bull trout). Strategy 3 WDFW will actively participate on the Joint Cabinet for Natural Resources and will work with Tribes, local governments, and private interest groups to implement watershed plans that protect and restore native char (bull trout), salmonids and other native fishes. WDFW will continue to participate in the Ahtanum/Cowichee Coordinated Resource Management Plan.

Strategy 4 WDFW will work within state laws and through the USFWS bull trout recovery planning process to implement management actions needed to provide functioning habitats for native char defined in the WSP habitat Policy Framework including: 1) habitat protection and management; 2) basin hydrology and stream flow (including suitable temperatures); 3) water sediment quality and sediment transport; 4) stream channel complexity; 5) riparian areas and wetlands; 6) lakes; and 7) marine areas.

Strategy 5 Use EDT model to identify priority reaches for preservation and restoration of habitat critical for maintaining life history stages of anadromous salmonids.

Strategy 6 Determine limiting factors in those reaches and develop plans to preserve and/or restore habitat.

Strategy 7 Develop new or improve existing fish passage facilities to allow full use of the existing habitat for salmonids within the Subbasin.

Objective 3 Enforce hydraulic project approvals and conduct follow-up investigations of Hydraulic Project Approvals to ensure permit compliance.

Strategy 1 Information related to native char (and other fish-bearing) waters (including spawn timing and locations) will be distributed to each habitat and TFW (Timber/ Fish/ Wildlife) biologist responsible for processing HPAs or reviewing environmental documents to ensure appropriate conditions are incorporated into these documents to protect native char habitat. WDFW fish program has provided Yakima subbasin habitat program biologists with locations and spawn timing.

Strategy 2 Compliance checks will be made to insure adherence to conditions of permitted activities.

Objective 4 Reduce water temperatures in specific sections of the basin, especially during times when anadromous fish are present

Strategy 1 Increase flows as described in above Objective 1.

Strategy 2 Revegetate riparian and wetland areas with native plants

Strategy 3 Groundwater infiltration

Strategy 4 Continue research on impacts of gravel mining on water temperature.

Strategy 5 Continue implementation of irrigation projects designed to improve water quality (including temperature) throughout the Subbasin.

Strategy 6 Enforce existing state and federal environmental regulations

Objective 5 Identify areas appropriate for habitat restoration

Strategy 1Continue development and use of EDT model to identify priority reaches for habitat restoration in the Subbasin.
Strategy 2 Develop prioritized plans based on model results, and pursue funding to implement restoration activities.
Strategy 3 Identify landscape connectivity needs in all habitats
Strategy 4 Develop GIS inventory of shrub-steppe (WDFW Sage Grouse Management Plan 1995) and other critical habitats in Yakima subbasin
Strategy 5 Develop prioritization plans based upon inventory information (Meuth 1989, Parker 1989, Bich et. al 1991, Ratti and Kadlec 1992)

Objective 6 Secure for restoration key habitats through purchase, easement, lease or other appropriate means (Meuth 1989, Parker 1989, Bich et. al 1991, YN 1994)
Strategy 1 Utilize existing funding opportunities (BOR, BPA, Nature Conservancy, state, tribal, and other sources) to secure identified priority key habitats for preservation and/or restoration for salmonids in the Yakima subbasin.
Strategy 2 Acquire approximately 20,000 acres of perpetual timber rights on WDFW lands, including Wenas and Oak Creek Wildlife Areas
Strategy 3 Acquire for restoration key parcels for connectivity in shrub steppe ecosystems
Strategy 4 Acquire for restoration wetland and riparian habitats (Meuth 1989, Parker 1989, Bich et. al 1991, Ratti and Kadlec 1992, YN 1994, YN 2001, Knutson and Leaf 1997, Hays et al. 1999)

Objective 7 Restore degraded terrestrial habitats
Strategy 1Evaluate shrubsteppe restoration activities, including the WDFW's and YN's habitat restoration efforts, the Conservation Reserve Program, and species-specific restoration activities on other public and private lands.
Strategy 2 Develop restoration guidelines for shrubsteppe habitat including grazing management, seed mixtures for revegetation efforts, weed control methods, and considerations for landscape configuration.
Strategy 3 Improve uplands for waterfowl nesting controlling weeds adjacent to wetlands, increasing amount of riparian shrub cover, and removing Russian Olive trees (Bich et al 1991, YN 1994, WDFW Sunnyside Wildlife Area Implementation Work Plan 1998)
Strategy 4 Increase the shrubsteppe habitat component while eliminating the agricultural cover type on the Sunnyside Wildlife Area (WDFW Sunnyside Wildlife Area Implementation Work Plan 1998)
Strategy 5 Protect, enhance, and manage the shrub-steppe and forest ecosystem habitats on the Wenas Wildlife Area for Rocky Mountain elk (Cervus elaphus nelsoni), mule deer (Odocoileus hemionus hemionus), bighorn sheep (Ovis canadensis), sage grouse (Centrocercus urophasianus), and other endemic/migratory wildlife species.
Strategy 6 Restore 1,730 acres of abandoned cropland to native like shrub-steppe habitat by the end of FY 2004.

Strategy 7 Reduce the amount of introduced vegetation by 50% along 350 miles of roads/trails and on 500 acres of shrub-steppe/riparian habitat by the end of FY 2005.

Strategy 8 Adjust road management for restoration and effective use of habitats through abandonment, rehabilitation, closure and appropriate maintenance (USDA/USDI 1997).

Strategy 9Utilize prescribed fire, thinning and other appropriate treatments to restore forested habitats and winter range (USDA/USDI 1997).

Strategy 10 Continue to develop, distribute, and monitor the use of bio-control agents (insects, microorganisms, etc.) for exotic weed control.

Objective 8 Restore degraded wetland and riparian habitats.

Strategy 1 Maintain and/or restore riparian habitat and improve water quality and conditions for fish within the Wenas Creek, Roza Creek, and Umtanum Creek drainages. (WDFW Wenas Wildlife Area Work Plan, 2000).

Strategy 2 Reduce sediments entering Umtanum Creek by the end of 2001 by improving the stream channel crossing (Durr road) in section 15, T16N,R18E.

Strategy 3 Restore hydrological function of wetland areas throughout the subbasin(Meuth 1989, Parker 1989, Bich et al 1991, Ratti and Kadlec 1992, YN 1994, YN 2001, Nordstrom and Milner 1997)

Strategy 4 Restore habitat for waterfowl and other species in wetland and riparian areas in the Yakima basin (Sunnyside Wildlife Area Implementation Work Plan 1998, Bich et 1991, Parker 1989, YN 1994, Ratti and Kadlec 1992)

Objective 9 Implement long-term monitoring on restoration sites (YN 1987, Meuth 1989, Parker 1989, Bich et. al 1991, Ratti and Kadlec 1992, YN 1994, WDFW Sunnyside Wildlife Area Implementation Work Plan 1998, WDFW Wenas Wildlife Area Work Plan 2000).

Strategy 1 Evaluate effectiveness of restoration efforts

Strategy 2 Adjust restoration efforts as necessary

Goal 3. Restore, maintain, and enhance fish and wildlife populations to sustainable levels and also, when applicable, harvestable levels.

Objective 1 Increase or establish salmonid stocks and runs to a level where they can maintain themselves through natural spawning and rearing.

Strategy 1 Protect and restore spawning, rearing and migration habitat as described under Goals 1 and 2.

Strategy 2 Establish spawning escapement goals for anadromous stocks in the Yakima basin.

Strategy 3 Use salmon and steelhead supplementation in the Yakima Subbasin because some wild stocks are persistently below the desired escapement and can not rebuild themselves due to factors other than fishing. Supplement where wild stocks are declining and is in danger of extinction; and to reintroduce salmon and steelhead to areas they historically occupied.

Strategy 4 Analyze the potential and develop plan to restore salmonids which may include supplementation of steelhead and other salmonids in Taneum Creek, consistent with the multi-agency purchase of the Heart K Ranch.

Strategy 5 Supplemented population levels should be consistent with the historic balance between steelhead, resident trout, salmon, etc.

Strategy 6 Supplemented populations should have similar morphological, physiological, behavioral, and life-history attributes as native Yakima River stocks.

Strategy 7Characterize the developmental physiology of supplemented stocks and compare and contrast it with that of naturally rearing stocks to develop rearing profiles for subsequent supplementation efforts.

Strategy 8 Fisheries will be regulated to meet escapement goals for hatchery broodstock and in selected cases where hatchery escapement is desired to supplement wild escapement.

Strategy 9 Anadromous rivers and streams should generally be closed to recreational fishing at least from April1 to May 31 to protect migrating smolts. However, the upper Yakima catch and release trout fishery will remain open year-round as will the lower Yakima will for harvest of warmwater fish species, which are predators of salmonids

Objective 2 Continue Cle Elum Supplementation and Research Program to evaluate use of supplementation as tool for rebuilding natural populations of salmon.

Strategy 1 Continue random collection of broodstock throughout duration of adult run at Roza Dam Adult Monitoring and Collection Facility.

Strategy 2 Rear 810,000 juveniles at the Cle Elum Facility.

Strategy 3 Release smolts volitionally from three acclimation sites.

Strategy 4 Monitor smolt and adult survival of experimental groups.

Strategy 5.Develop and implement genetic research program to evaluate the impacts of supplementation on the genetic structure of spring chinook population.

Strategy 6.Develop and implement reproductive ecology research to evaluate the reproductive behavior and success of supplementation fish. Use the spawning channel at the Cle Elum Facility to compare the behavior, mate selection, and spawning success of hatchery reared and wild adult spring chinook salmon. Use DNA profiling to evaluate the success (# of progeny) of spawning hatchery reared and wild adults.

Strategy 7.Identify and monitor the potential ecological interactions that may result from supplementation.

Objective 3 Continue feasibility study of reintroduction of coho salmon into the Yakima subbasin.

Strategy 1 Release 1,000,000 coho smolts from 4 acclimation sites in the upper Yakima and Naches rivers.

Strategy 2 Conduct experiments to determine appropriate broodstock, release timing, and smolt and adult survival.

Strategy 3 Monitor radiotagged adults to determine homing fidelity to release site and spawning success.

Objective 4 Continue supplementation of the mainstem and Marion Drain populations of fall chinook in the lower Yakima River.

Strategy 1 Continue evaluations of brood stock collection in Marion Drain.

Strategy 2 Spawn adults, rear and release juveniles from acclimation sites for both Marion Drain and mainstem populations of fall chinook.

Objective 5 Determine feasibility of using reconditioned steelhead kelts to rebuild ESA listed steelhead populations in the Yakima subbasin.

Strategy 1 Collect outmigrating steelhead kelts at Chandler Juvenile Monitoring and Evaluation Facility.

Strategy 2 Hold kelts at Lower Yakima Production Facility and evaluate diets to induce feeding and promote recovery, growth, and gonad development.

Strategy 3 Determine reproductive development of reconditioned fish, and release into Yakima.

Strategy 4 Radiotrack released adults and determine spawning distribution and success.

Objective 6 Conserve the genetic diversity and integrity of all wild salmon and steelhead populations and resident trout in the Yakima subbasin.

Strategy 1 Protect and restore spawning, rearing and migration habitat as described under Goals 1 and 2.

Strategy 2 Develop and monitor genetic profiles for stocks of salmon, steelhead, and trout in the Yakima Subbasin.

Strategy 3 For each wild stock/run, except supplementation and conservation areas, interbreeding between hatchery and wild fish will be limited to allow no more than a 10% reduction in the long term reproductive potential of the wild stock/run.

Strategy 4 Impacts and appropriate stocking levels will be calculated using the WDFW's genetic conservation model (Hulett and Leider 1993) and the genetic conservation model user's guides (Johnson 1993, Johnson and Hulett 1993).

Strategy 5 Broodstock for chinook and steelhead supplementation should come from indigenous stocks.

Strategy 6 Broodstocks for extirpated stocks of salmon and steelhead will be developed from genetically appropriate sources.

Strategy 7 Additional genetic profiling of westslope cutthroat trout is necessary to determine genetic structure of populations (Trotter et al., 1999).

Objective 7 Rear hatchery salmon, steelhead, and trout to provide recreational and tribal fishing opportunities.

Strategy 1 All hatchery steelhead smolts released to provide adult steelhead for harvest will be adipose marked prior to release to allow the selective harvest of hatchery steelhead adults.

Strategy 2 To maintain and increase genetic diversity of hatchery broodstocks, the selection of one or more attributes (e.g. run time, size, age) from a population will be minimized.

Strategy 3 To minimize wild steelhead interactions with hatchery fish, summer steelhead smolts will be released into the Yakima River drainage during April 15 through June 1. The average size of the population released will be 3.00 - 7.00 fish/pound with a target average condition factor (K) in the range of 0.90 - 0.99.

Strategy 4. To minimize adverse fishery impacts on wild salmon and steelhead, conservation areas will be set aside where no stocking of hatchery steelhead will be allowed. To select conservation areas, stocks or runs will be identified that represent genetic diversity within and between stocks, life history variability, and habitat diversity and complexity and will reflect a broad range of geographic areas.

Strategy 5. Enforce harvest regulations for wild steelhead (e.g. wild steelhead release, closed areas and seasons) as the highest enforcement priority. Licensing requirements, bag limits, gear restrictions, etc. on wild and hatchery fish will also be enforced, but are a lower priority.

Strategy 6.Release hatchery trout, primarily in lakes to provide sport fisheries. Consider and investigate potential downstream impacts to salmonid fisheries.

Objective 8 Provide recreational and tribal anglers the opportunity to catch and harvest steelhead, salmon, and trout.

Strategy 1 Harvestable wild and hatchery salmon and steelhead will be allocated between treaty and non-treaty fishermen.

Strategy 2. Harvest fisheries will allow the opportunity to harvest hatchery and wild fish that are surplus to the escapement goal.

Strategy 3.Catch-and-release fisheries will be used to maximize catch (or catch rate) and provide extended fishing periods. Catch-and-release fisheries must be consistent with wild fish protection guidelines and selective fishery regulations.

Objective 9. Monitor and evaluate the diversity and productivity of steelhead stocks/runs and their habitats.

Strategy 1. Monitor recreational and tribal harvest through creel censuses, permit card returns, commercial fish buyers' tickets and tribal reporting. Conduct recreational angler preference surveys to establish the allocation of recreational opportunity. Strategy 2. Monitor spawning escapement on all river/stream systems presently surveyed; expand surveys as resources allow. Review wild spawner escapement policies, goals and estimation methods and update periodically to ensure consistency with the productive capacity of the habitat.

Strategy 3. Inventory steelhead habitat statewide and periodically evaluate its status.

Strategy 4 Annually update steelhead stock summary tables for all stocks and runs. (Tables document harvest, escapement, and run sizes.) Prepare a concise annual status report on all stocks.

Strategy 5 Establish a baseline of genetic information by conducting a genetic stock identification study on Yakima basin steelhead stocks. Estimate the appropriate smolt stocking levels using the WDFW's genetic conservation model at least every five years. Monitor genetic risks and assess factors influencing genetic diversity of steelhead stocks including hatchery fish, harvest and habitat actions every five years. Periodically evaluate genetic conservation guidelines to ensure steelhead genetic diversity is conserved.

Strategy 6 Monitor and evaluate broodstock management and incubation and rearing techniques and methods to maximize survival while being consistent with wild fish protection guidelines.

Objective 10 Reestablish stocks in historically inhabited areas. Stocks will be provided mechanisms (e.g. re-establishing migration corridors) that will promote natural recruitment of native char to formerly inhabited areas. In areas where the success of natural recruitment is improbable, supplementation may be employed to seed these areas.

Strategy 1 Where possible, natural recruitment of stocks will be promoted to seed native char historical areas.

Strategy 2 If reestablishing stocks via natural recruitment is not feasible, supplementation may be used to restore stocks. . No char supplementation projects have been proposed for the Yakima subbasin.

Objective 11 Maintain and restore stock abundance and natural biological characteristics. All stocks will be managed to maintain recruitment levels that ensure stable or increasing population densities of all native char life history forms present, and a natural age structure through maturation.

Strategy 1. Where habitat is limiting, implement measures to restore habitat necessary for sustaining critical life history stages of native char including spawning and rearing.

Strategy 2. Manage recreational fisheries to ensure through minimum size limits, that one full age class of mature females is allowed to spawn at least once prior to being subject to harvest. This will be defined as the youngest age class with a majority (more than 50%) of mature females and may vary depending on life history forms and specific population characteristics. Recreational fisheries for bull trout have been closed in the Yakima subbasin.

Strategy 3. Sanctuaries and refugia will be used to protect some stocks from the effects of degraded habitat, harvest management strategies, and hatchery influences. A number of waters and stream sections important for bull trout spawning and rearing have been closed to all recreational fishing in the Yakima subbasin.

Objective 12 Maintain existing fish passage facilities and screens, construct fish passage where existing man caused barriers impede or prevent fish

passage, and fabricate and construct fish screening facilities as necessary to protect the fisheries resources.

Strategy 1 Conduct annual operation and maintenance of BPA funded fish passage facilities and screening facilities.

Strategy 2 Inventory streams (i.e. SSHIAP or similar program) to identify fish passage barriers for anadromous and resident salmonids.

Strategy 3 Enforce existing state fish passage and screen requirement regulations.

Strategy 4 Identify and repair, or remove, or relocate roads and culverts that are susceptible to mass wasting and bank failures; that negatively impact riparian areas, and inhibit connectivity and natural stream functions in resident fish watersheds. Replace culverts that are passage impediments. Restore passage at irrigation diversions where passage is identified as a need, for example, Big Creek.

Strategy 5 Coordinate with the USBR and other entities regarding the finalization of remaining Phase II screening facilities, and the scheduling, fabrication, and construction of potential Phase III screening facilities.

Objective 13 Maintain and restore lake and reservoir habitats that are conducive to wild salmonid passage, rearing, adult residency and spawning.

Strategy 1 Enforce existing state and federal environmental regulations.

Strategy 2 Coordinate reservoir water level management with USBR.

Strategy 3 Form partnerships, and participate at all levels of government to assess and maintain quality fish and wildlife habitat.

Objective 14 Conserve genetic diversity of stocks. Genetic diversity will be maintained within and among stocks to allow local adaptation to occur with changing environmental conditions over the long term.

Strategy 1 Habitat will be protected so that the distribution and amount of habitat is sufficient to maintain genetic diversity and promote local adaptation. The Department will work to protect migratory corridors that are essential to provide connectivity among populations.

Strategy 2 Where brook trout and native char currently overlap, the management emphasis will be to reduce or eliminate hybridization between them. Brook trout will only be stocked in waters that are permanently isolated from native char to avoid any likelihood of interaction. Stocking of brook trout has been significantly reduced in the Yakima subbasin the past 5 years.

Objective 15 Recreational fisheries will only be allowed on healthy stocks with surplus production. Consistent with the population maintenance objectives, fishery management efforts emphasize resource protection of native char stocks by restricting recreational fishing and harvest. Fisheries will be managed consistent with the strategies described *in* A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington (BFMS) (Washington

Department of Game, 1984). **Fisheries management will be based on the following principles: Recreational fisheries will only be allowed on healthy stocks with surplus production.**

Strategy 1 Directed sport fisheries on char will only be allowed on healthy stocks with harvestable surplus. Minimum size limits will be set based on life history type to ensure that a full age-class of females spawn at least once prior to recruitment into the fishery. This will be defined as the youngest age class with a majority (more than 50%) of mature females.

Strategy 2 Fishing closures for all species will be implemented in areas and times when there is a need to protect critical spawning and rearing native char and when abundance is so low that a stock can't tolerate incidental harvest. Fishing closures have been adopted in major spawning areas, sections of N. F. Ahtanum Creek, Box Canyon Creek, Deep Creek, Gold Creek, Indian Creek, and S. F. Tieton River.

Strategy 3. Selective gear restrictions (e.g. use of single barb-less hooks and bait restrictions) for all species will be implemented in areas and at times when there is a need to protect critical spawning and rearing char. Selective gear regulations have been adopted in many Yakima subbasin rivers and streams.

Objective 16 Enforce seasons and species-specific fishing regulations. Regulations governing fishing in areas where native char occur will be enforced to ensure angler compliance.

Strategy 1 The Fish Program will coordinate with the Enforcement Program to identify and prioritize waters for enforcement emphasis activities. Data on violations will be reviewed periodically to assess angler compliance with regulations. Fish Program has provide a list of waters and spawn time to Yakima subbasin Enforcement officers.

Objective 17 Assess and monitor populations (YN 1987, Meuth 1989, Parker 1989, Bich et. al 1991, YN 1994, Nordstrom and Milner 1997, Nordstrom and Reiner 1997, Nordstrom and Whalen 1997, McAllister 2001, McAllister et al 1999, Hays et al 1999, US Fish and Wildlife Service 1993, Potter et al 1999, WDFW 2001)

Strategy 1 Conduct base line inventories and population assessments for species where insufficient or no population and distribution information exists such as jackrabbits, burrowing owls, amphibians, bats, small mammals, invertebrates and others (Meuth 1989, 1996, Nordstrom and Milner 1997, Nordstrom and Reiner 1997, Nordstrom and Whalen 1997, McAllister 2001, McAllister et al 1999, Hays et al 1999, US Fish and Wildlife Service 1993, Potter et al 1999)

Strategy 2 mprove our understanding of baseline ecology of golden eagles, goshawks, white-headed woodpeckers, sharptail snakes, and other species, in the Yakima Subbasin and prevent further declines that would lead to a state or federal Threatened or Endangered listing (Nordstrom and Milner 1997, Nordstrom and Reiner 1997, Nordstrom and Whalen

1997, McAllister 2001, McAllister et al 1999, Hays et al 1999, US Fish and Wildlife Service 1993, Potter et al 1999, WDFW 2001, Hays and Desimone 1999, Marshall 1997).

Strategy 3 Continue existing population monitoring efforts (Meuth 1989, YN 2000, Nordstrom and Milner 1997, Nordstrom and Reiner 1997, Nordstrom and Whalen 1997, McAllister 2001, McAllister et al 1999, Hays et al 1999, US Fish and Wildlife Service 1993, Potter et al 1999, WDFW 2001, Hays and Desimone 1999, Marshall 1997)

Strategy 4 Monitor population response to protection, restoration and management efforts (Meuth 1989, Millspaugh and Skalski 1999, Hays and Desimone 1999, YN 2000)

Strategy 5 Determine habitat associations of shrub-steppe obligate and shrub-steppe associated species such as sage sparrows, Brewer's sparrows and sagebrush voles at both local and landscape scales.

Objective 18 Write recovery plans for species requiring such action.

Strategy 1 Utilize population, habitat and limiting factor information to develop recovery efforts

Objective 19In the lower Yakima Basin maintain current waterfowl production levels and increase average wintering duck numbers to 100,000.

Strategy 1 Increase the amount of waterfowl wintering habitat and winter food resources in the Lower Yakima Basin to allow for the redistribution of wintering waterfowl back into the Yakima Basin (Lloyd et. al 1983, Meuth 1989, Parker 1989, Bich et. al 1991, YN 1994)

Objective 20 Increase Washington state sage grouse population to 1,500 birds. The population should consist of at least three distinct sub-populations: 500 sage grouse in Management Zone 2; 500 sage grouse in Management Zone 4; and 250 sage grouse in either Management Zone 1, 3, 5, or 6. An additional 250 sage grouse should also be scattered through Management Zones 1, 3, 5, or 6 [Yakima Subbasin is recovery Zone 6] (WDFW State Management Plan for Sage Grouse, 1995).

Strategy 1 Assess potential sage grouse habitats within the Yakima Subbasin through standardized mapping efforts used throughout the Columbia Plateau.

Strategy 2 Improve quantity, quality, and configuration of the shrubsteppe habitat necessary to support a viable population of sage grouse.

Objective 21 Recover ferruginous hawks from threatened status by maintaining a population of at least 60 nesting pairs statewide, including at least 40 pairs in the Central Recovery Zone (WDFW1996).

Strategy 1 Improve our understanding of the suitability and security of ferruginous hawk nesting habitats (Goal 3.1 and Research Topics in section 7 of Recovery Plan, WDFW 1996).

Strategy 2 Assess the importance of survival rates and contaminants of adult and juvenile ferruginous hawks to low rates of nest occupancy, and relate these to hawk movements (Goal 3.1 of WDFW Recovery Plan, 1996).

Strategy 3 Improve ferruginous hawk nest occupancy.

Objective 22(a) Maximum fishing, hunting and non-consumptive recreational opportunities compatible with healthy, diverse fish and wildlife populations. (WDFW 1999, WDFW 2000, WDFW2001)

Strategy 1 Monitor harvest of fish and wildlife (Meuth 1989, WDFW 1999, WDFW 2000, WDFW2001)

Strategy 2 Use population and harvest information to predict changes (Meuth 1989, WDFW 1999, WDFW 2000, WDFW2001)

Strategy 3 Increase access opportunities for public hunting, fishing and non-consumptive wildlife recreation

Objective 22(b) Establish controls for the orderly harvest of species to maintain perpetual food sources and to make full productive economic use of selected game (YN 1987).

Strategy 1 Monitor harvest of fish and wildlife (Meuth 1989)

Strategy 2 Use population and harvest information to predict changes (Meuth 1989)

Strategy 3 Manage wildlife areas to maintain populations and to meet harvest goals (Lloyd et. al 1983, YN 1987, Meuth 1989, Parker 1989)

Strategy 4 Improve the amount and quality of waterfowl and upland game bird hunting areas (Lloyd et. al 1983, YN 1987, Meuth 1989, Parker 1989)

Goal 4: Increase the information and knowledge needed to restore and manage fish, wildlife and their habitats.

Objective 1 Develop and use methodologies to monitor changes in habitat, water quality, and fish and wildlife populations.

Strategy 1 Continue water quality monitoring programs that are ongoing in the Subbasin.

Strategy 2 Develop programs to monitor water quality in identified locations.

Strategy 3 Develop and use habitat monitoring methodologies to track changes in habitat condition in the Subbasin.

Strategy 4 Develop and use methodologies to monitor fish and wildlife populations in the Subbasin.

Objective 2 Continue ongoing and develop new research to monitor and improve water, habitat, and fish and wildlife populations in the Yakima subbasin.

Strategy 1 Numerous water quality and quantity monitoring and improvement programs are currently underway in the Yakima Subbasin. We need to continue these programs and develop and prioritize new research, monitoring and implementation programs to improve the water quality and maximize beneficial use of current water supply.

Strategy 2 Develop and use methods to restore normative watershed function to the Yakima river and its associated habitats for fish and wildlife.

Strategy 3 Continue ongoing research on fish and wildlife populations in the Subbasin. Develop and prioritize new research programs that address holistic approach to recovering fish and wildlife in the Yakima Subbasin.

Objective 3 Develop and use information systems to inform the public and interested managers throughout about information developed in the Yakima subbasin.

Strategy 1 Develop and use websites and other information sources to distribute information from research and monitoring on the Yakima to interested public, scientific communities, and resource managers.

Objective 4 Inform the public regarding proper identification of native char species and need for their protection.

Strategy 1 Enforcement contacts with the public in the field will inform anglers of proper identification and conservation need for native char. Strategy 2 Written and pictorial information will be distributed to the public to increase awareness of proper identification and conservation need for native char. Signs with colored picture of bull trout have been posted on many Yakima subbasin waters. Bull trout information is posted on WDFW webpage: www.wa.gov/wdfw/outreach/fishing/char.

Objective 5 Monitor fisheries as well as native char stocks and habitats to evaluate actions in meeting the management goal and objectives for native char. WDFW will monitor fisheries to ensure that direct and incidental harvest do not adversely impact long-term productivity of native char stocks.

Strategy 1 Native char harvest will be monitored by Department Fish and Wildlife Officers during routine and emphasis patrols.

Strategy 2 WDFW may conduct creel surveys to estimate the harvest of native char in directed fisheries and incidentally caught in other fisheries.

Strategy 3 WDFW will determine the feasibility of expanding the current catch record card for recording harvest of native char species.

Strategy 4 Conduct angler surveys periodically to determine anglers' knowledge, opinions, and preferences regarding native char management.

Objective 6 Monitor habitat quality and quantity. Inventory and assess native char habitat periodically to evaluate changes in habitat quality and quantity over time.

Strategy 1 Conduct an inventory and assessment of native char habitat to evaluate changes in basin hydrology and stream flows, water and sediment quality and sediment transport, stream channel complexity, riparian and wetlands, lakes and reservoirs, marine areas and fish passage and access. Big Creek is currently blocked by a diversion dam that prevents upstream bull trout migration. Historical status of bull trout in Big Creek is unknown but Big Creek has potential if fish passage facilities are constructed.

Objective 7 Determine distribution of native char stocks. Standardized methodologies will be used to quantitatively determine the distribution of native char stocks in Washington.

Strategy 1 Standard methodologies identified in Bonar et al. (1997) will be used to collect and analyze distribution data. Distribution data will be maintained in a Geographic Information System database. Surveys have and will continue to be conducted in the Yakima subbasin to determine distribution.

Objective 8. Determine stock abundance and biological characteristics. The status (abundance and natural biological characteristics) of native char stocks will be assessed and the bull trout and Dolly Varden salmonid stock inventory will be updated biennially.

Strategy 1 Stock abundance information will be collected using methods presented in Bonar et al. (1997). Abundance data will be maintained in the Salmonid Stock Inventory database. Annual bull trout spawning surveys are conducted in known spawning index areas in the Yakima subbasin. This data will be provide for SaSI updates.

Strategy 2. Information on biological characteristics such as life histories, size, and age classes, of native char stocks will be collected and reported in annual reports and maintained in the electronic databases. WDFW, USFW, BOR and CWU have cooperatively collected biological data in the Yakima subbasin and will continue to do so.

Strategy 2. Abundance and biological data will be evaluated biennially to update the status of native char stocks. An annual summary is produced for the Yakima subbasin. This information will be provide for updates to the SaSI document.

Objective 9. Determine genetic diversity of native char stocks. Genetic analysis will be used to determine distribution of bull trout and Dolly Varden in Washington, identify stocks, identify their Major Ancestral Lineages and Genetic Diversity Units, and identify the genetic relationships among the different native char life history types.

Strategy 1 Native char stocks will be sampled for genetic analysis using non-lethal means (fin clips). Limited fin tissue samples have been collected in the Yakima subbasin.

Strategy 2 Fin tissue samples will be analyzed by the Department using microsatellite DNA techniques. Limited analysis of Yakima subbasin stocks has been completed.

Objective 10. Determine length at maturity and frequency of spawning for individual stocks.

Strategy 1 Determine reproductive frequency and length at maturity for stocks that currently have, or are expected to have, targeted harvest fisheries. Adjust minimum length criteria to ensure the age class containing the majority of females (as defined earlier) can spawn at least once prior to recruitment into the fishery. Length data has been collected for some stocks, but harvest seasons remain closed. (Unless stock specific information is available the minimum length criteria will be: 8-12 inches for resident fish, 20 inches for fluvial fish, 24 inches for adfluvial, and 20 inches for anadromous fish. Bull trout harvest is closed in the Yakima subbasin.)

Objective 11. Determine relationships among native char life history types. It is probable that there is some level of genetic exchange among the four life history forms of native char. The extent of genetic exchange among resident, fluvial, adfluvial, and anadromous native char is largely unknown.

Strategy 1 Develop and implement research strategies to determine interactions between native char life history types. Cooperative WDFW/CWU bull trout research projects have been implemented on Deep Creek and Rimrock Lake and other waters.

Objective 12 Develop and employ programs to educate the public and students in K through 12 about the knowledge and skills needed to restore and manage fish, wildlife, and their habitats.

Strategy 1 Provide educational training, materials and support for teachers.

Strategy 2 Provide the opportunity for students to share the results of their field work and observations with other students both in and outside the Yakima subbasin through such means as science fairs, e-mail, and the websites.

Strategy 3 Form partnerships between teachers and students and scientific and technical professional across a broad spectrum of resource activities and interests involved in watershed and resource management.

Strategy 4 Provide relevant, hands-on field-oriented environmental education opportunities for students, focusing on water, aquatic life and watershed management.

Objective 13 Increase understanding of how individual decisions and actions effect fish, wildlife and their habitats.

Strategy 1 Foster partnerships that provide opportunities for students and citizens to participate in volunteer projects monitoring water quality, developing and maintaining nature trails, restoring fish and wildlife habitat, and collecting field data among other activities.

Strategy 2 Develop public outreach programs in the basin that explain fish and wildlife restoration issues, choices, management decisions and how individual citizens can be involved

Objective 14 Develop education programs in fish and wildlife management and culture for Yakama Nation members.

Strategy 1. Implement program to educate Yakama Nation members at two and four years college programs to pursue degrees in fish and wildlife culture and management methods.

Research, Monitoring, and Evaluation Activities

The following are current and on-going projects. Completed research projects are described in Existing and Past Efforts.

Anadromous Fish

Physiological Assessment of Wild and Hatchery Spring Chinook Salmon

From 1992 to 1997 Beckman et al. (2000) conducted a BPA sponsored project to comprehensively assess the physiology of naturally rearing juvenile spring chinook salmon in the Yakima River. Physiological characters measured in hundreds of juvenile chinook included body size, condition factor, liver glycogen, body lipid, gill Na+/K+ ATPase activity, and plasma hormone levels of thyroxine (T4) and insulin-like growth factor-I (IGF-I). Results from this study were used to create a physiological template for juvenile spring chinook salmon in the drainage and provided a baseline for the future culture of spring chinook at the Cle Elum Supplementation and Research Facility (initiated in 1997).

From 1998 to the present, NMFS biologists (BPA project #199202200) have been conducting research to characterize the physiological development of the first three brood years (BY 97, 98, 99) of hatchery spring chinook salmon produced at the Cle Elum Supplementation and Research Facility under the semi-natural (SNT) and old conventional (OCT) rearing strategies (see section on artificial production of spring chinook for description). Fish are sampled at the Cle Elum hatchery, at remote acclimation sites at Clark Flat and Jack Creek, and at Roza, Prosser, and John Day Dams during outmigration. The physiology of these hatchery fish is being compared with physiological profiles for wild spring chinook compiled by Beckman et al. (2000) and with data from co-migrating wild fish collected at Roza, Prosser, and John Day Dams.

One of the most significant observations from the physiological analysis to date is the apparently high incidence of yearling precocious males ("minijacks") in the hatchery population. At the acclimation sites in the spring, prior to and during volitional outmigration, approximately 30-60% of the males examined showed advanced testicular development characteristic of 1+ precocious maturation (BY 97 Clark Flat: 89 out of 200 males; BY 98 Clark Flat: 97 out of 161 males, Jack Creek: 79 out of 155 males). These visual observations were later confirmed both histologically and through plasma steroid analysis. Precociously maturing hatchery fish were also collected at downstream dams during outmigration; however, the incidence was much lower (11-17%) suggesting that the majority of precociously maturing hatchery males do not migrate to the ocean. Finally, less than 0.5% of the wild spring chinook sampled at the downstream dams were precociously maturing.

Two year classes of precociously maturing wild spring chinook have been identified in the Yakima River (pers. comm. Pearsons, WDFW). Although the incidence of precocious maturation in this and other naturally rearing spring chinook populations is poorly characterized, from the small quantity of data available, the incidence is believed to be quite low (<5%). While precocious male maturation represents a natural life-history strategy for Yakima spring chinook, the hatchery environment may be artificially encouraging this developmental pathway beyond natural levels. Numerous studies have shown that maturation in male spring chinook salmon is highly influenced by rearing conditions. Alterations in the normal life-history composition of salmon populations are undesirable in hatchery supplementation due to loss of potential returning anadromous adults, effects on male/female sex ratios, and negative genetic and ecological impacts on wild populations and other native species. These impacts may include increased straying, predation, and competition with native fish species for limited resources and habitat.

Described are current or proposed research, monitoring and evaluation activities that are needed for ongoing projects. (Completed research is described under “Existing and Past Efforts.”) The explanations below include the biological context and reasons for particular courses of action as well as the methodologies to be employed. the rationale and methods.

Yakima Spring Chinook Artificial Production / Research

The survival of the semi-natural treatment (SNT) with overhead and instream cover, underwater feeders, and painted substrate was compared to the Optimum Conventional Treatment (OCT) and to the survival of wild fish tagged at Roza Dam. Survival to McNary Dam of PIT-tagged hatchery fish released in the Yakima basin was assessed for year 1999 and 2000 outmigrants (Figures 82 and 83). The general method used was to expand the number of fish detected at McNary (McN) by the estimated proportion of the release's McN passage that were detected at that site (McN detection rate). The expanded number was then divided by the number of fish released. The method used involved stratification of passage days based on estimated daily detection rates and used an independent stratification of McN-to-downstream-dam travel times since McN-detection-rate estimates were based on downstream dam detections. The method is discussed in detail in The 2000 YKFP Annual Report to Bonneville Power Administration.

Outmigration year 1999 gave higher survival indices but similar comparative results as year 2000. Using Bonneville-based estimates of McN detection rates, year 2000 had a Clark-Flat-to-McN survival index that was 78.4% of that in 1999 and a Easton-to-McNary survival index that was 66.5% of that in 1999. In 1999 there were no acclimation raceways at Jack Creek, and there were only two raceways per treatment at Easton. (In year 2000 there were three raceways/treatment at Easton and Clark Flats and two raceways/treatment at Jack Creek.) The survival indices in 1999 were based on time of tagging-to-McN survival instead of time-of-raceway-departure-to-McN survival because the PIT-tag detectors in the raceway outfalls were not functioning properly in 1999; therefore, survival-index estimates in 2000 would be expected to be even relatively lower than those in 1999 if raceway 1999 outfall detections were used for the release numbers as they were in 2000.

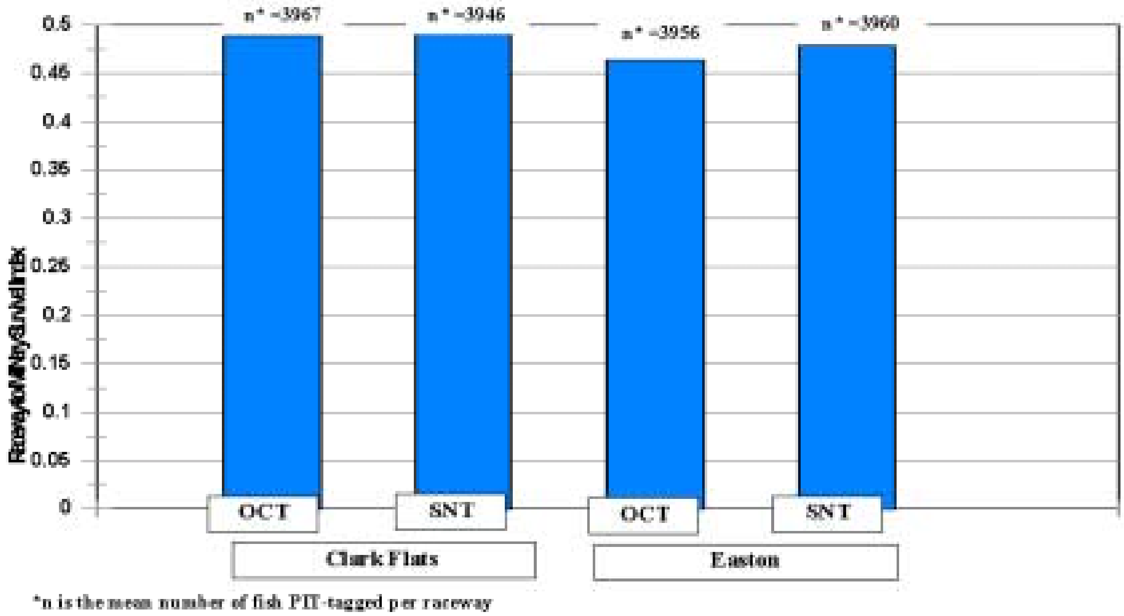


Figure 82. Pooled PIT-tagging-to-McNary survival indices of 1999 outmigrating OCT and SNT smolts.

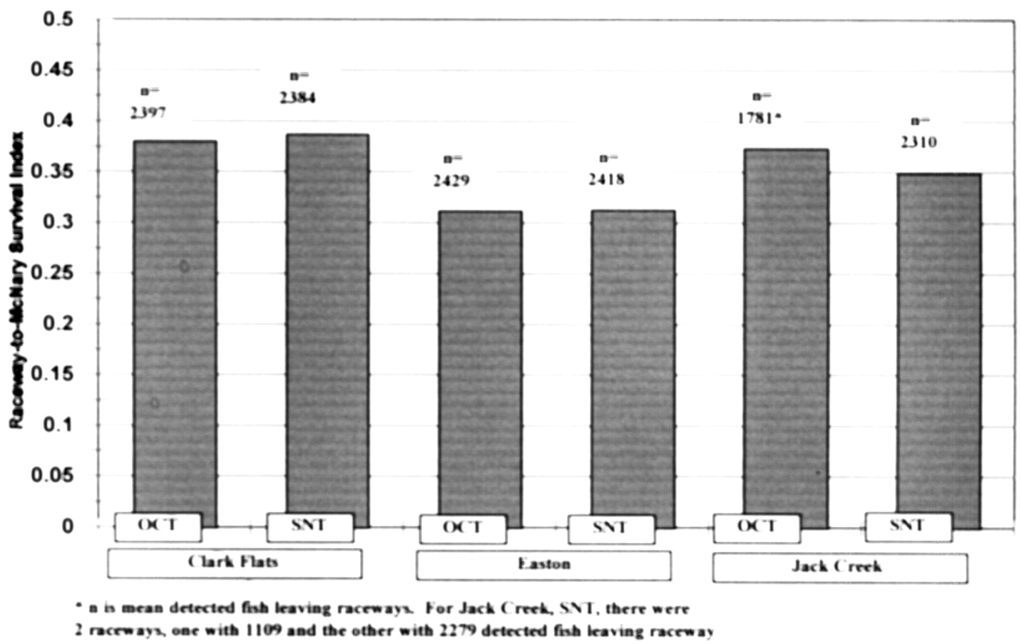


Figure 83. Pooled acclimation-site-to-McNary survival indices of 2000 outmigrating OCT and SNT smolts.

Table 55. Roza release numbers, Roza-to-McNary survival-index estimates, and McNary unexpanded detections for wild previously tagged, and previously untagged fish that were released at Roza (outmigration year 2000)

Release Period 1999 - 2000		Wild			OCT-SNT Tagged			OCT-SNT Untagged		
		Number Released	Survival Index	Detections[1]	Number Released	Survival Index	Detections[1]	Number Released	Survival Index	Detections[1]
7-Dec	2-Jan	158	0.320	18						
3-Jan	9-Jan	1575	0.305	171						
10-Jan	17-Jan	845	0.307	92						
18-Jan	24-Jan	435	0.252	39						
25-Jan	7-Mar	2401	0.446	381	111	0.286	11	86	0.304	9
8-Mar	22-Mar	333	0.431	51	116	0.202	8	454	0.291	46
23-Mar	30-Mar	191	0.519	35	141	0.495	24	381	0.245	32
31-Mar	13-Apr	171	0.564	34	328	0.200	23	351	0.226	27
14-Apr	26-Apr	51	0.364	6	226	0.295	21	401	0.378	48
27-Apr	6-May	49	0.315	5	127	0.297	11	277	0.250	21
Strata 1-4 Pooled		3013	0.299							
Strata 5-10 Pooled		3196	0.452	512	1049	0.281	98	1950	0.281	183

1 Unexpanded Detections

As in year 2000, in 1999 there were no significant differences among treatments (Type 1 P = 0.42) or between site x treatment interaction effects (Type 1 P = 0.65). As in 2000, Easton had a smaller 1999 survival index (0.471) than Clark Flats (0.490) using the Bonneville-based estimates of McN detection rates; however, the Type 1 error probability was much larger in 1999 than in 2000 (Type 1 P = 0.14 in 1999 but P < 0.01 in 2000).

Survival from Roza to McNary

Wild fish and OCT-SNT hatchery fish passing Roza Dam were sampled and PIT-tagged if not previously tagged and released for the purpose of assessing survival to McNary. Releases were grouped into strata in a manner to attain a minimum of 5 undetected detections for each release group (wild, previously tagged OCT-SNT fish, not-previously tagged fish) or to have a reasonably consolidated period of days within strata. The number of fish released at Roza, survival index estimates, and unexpanded detections at McNary within strata are presented in the Table 54 and subsequent Figure 84.

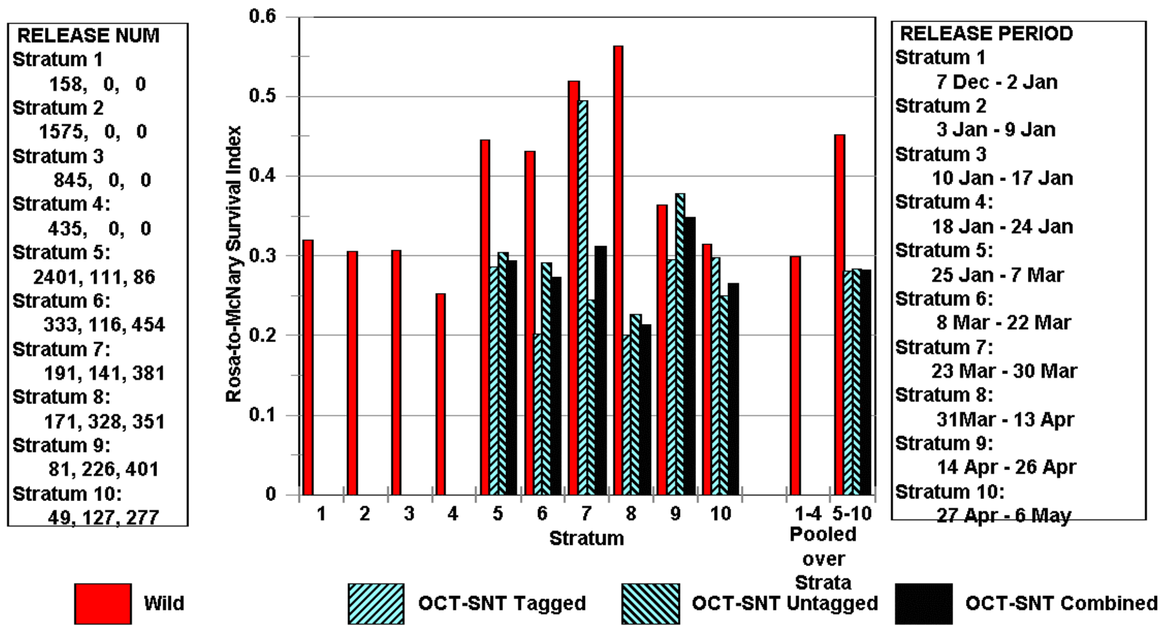


Figure 84. Rosa-to-McNary survival indices of wild and previously tagged, untagged and combined OCT-SNT fish within release strata.

Returning Adults

The first adult returns to the project occurred in 2000 with 740 total jacks returning to Roza adult facility. As with the smolts there was no significant difference between the SNT and the OCT treatments. It is believed that this lack of difference in survival as outmigrating smolts and returning adults is due to the very high flows and turbid water during the outmigration period for both of these years of releases. The smolts were carried downstream rapidly and were few avian predators were observed to be feeding in the Yakima river corridor. In years of low flow, as is expected for 2001, numerous gulls and other avian predators are observed to be feeding on smolts in the river, especially near bypass outfalls of diversion dams. It is assumed that predatory fish also had lower rates of feeding on the 1999 and 2000 outmigrating smolts due to the high flows.

Yakima/Klickitat Fisheries Project (YKFP)

In 1990, the Northwest Power Planning Council stated, “the purpose of the Yakima/Klickitat Production Project is to test the assumption that new artificial production can be used to increase harvest and natural production while maintaining genetic resources. It also emphasized that careful evaluation of supplementation and employment of adaptive management methods will be needed to accomplish this purpose. Such an approach should add the benefits of learning about supplementation and hatchery systems while contributing to the Council’s goal of increasing salmon and steelhead runs in the Columbia River Basin.”

The Yakima Fisheries Project developed the "Spring Chinook Supplementation Monitoring Plan" (Busack 1997) in response to this directive. The following is a listing of the current research tasks being conducted under this program. The project determined that the monitoring should achieve the following three objectives.

- YKFP monitoring should evaluate the success (or lack of it) of project supplementation efforts and its impacts, including juvenile survival, natural production and reproductive success, ecological interactions, and genetics;
- YKFP monitoring should be comprehensive; and
- YKFP monitoring should be done in such a way that results are of use to salmon production efforts throughout the Columbia basin and the region.

With the above principles as a backdrop, the project's Science/Technical Advisory Committee (STAC) and Monitoring Implementation and Planning Team (MIPT) developed the M & E action plan in three phases. The first phase was primarily conceptual. STAC and MIPT defined critical issues and problems, and identified associated response variables. The second phase was quantitative, which determined the scale and size of an effective monitoring effort. A critical element of the quantitative phase was an assessment of the precision with which response variables can be measured, the probability of detecting real impacts, and the sample sizes required for a given level of statistical precision and power. The third and final phase was logistical. At this point the feasibility of monitoring measures have been evaluated as to practicality and cost. Currently research, monitoring and evaluation projects are ongoing in four areas of concern—natural production, harvest, genetics, ecological interactions—and are described below.

Natural Production - YKFP

The overall monitoring and evaluation objective is to develop methods of detecting indices of increasing natural production, as well as methods of detecting a realized increase in natural production, with specified statistical power.

1. Modeling

YN and WDFW are developing computer models to help design complementary supplementation and habitat enhancement programs for targeted stocks. The models will incorporate empirical estimates of life-stage-specific survival and habitat quality and quantity. Biologists will diagnose the fundamental environmental factors limiting natural production and estimate the relative improvements in production that would result from a combination of habitat enhancement and supplementation using the "Ecosystem Diagnosis and Treatment" (EDT) model.

2. Yakima River juvenile spring chinook microhabitat utilization

WDFW is estimating the baseline microhabitat utilization of juvenile spring chinook salmon. This research is necessary because even if YFP supplementation were perfect—producing smolts and adults identical to wild fish in every way—the project could fail if existing production actually represented the carrying capacity of the Yakima basin. A number of indices have been proposed to monitor carrying capacity and one of them is the change in microhabitat utilization by early parr.

Under excessive densities, a significant proportion of spring chinook parr might be displaced into sub-optimal microhabitats. Accordingly, the methodology researchers will use involves monitoring the relative incidence of early spring chinook parr in "typical" (baseline) and "atypical" microhabitats as a function of estimated egg deposition and spawning escapement. Snorkelers will mark the location of spring chinook focal positions and then measure the physical parameters of the focal position.

3. Yakima River juvenile spring chinook marking

YN continues to estimate hatchery spring chinook smolt-to-smolt survival at Chandler Juvenile Monitoring Facility (CJMF) and Columbia River projects and smolt-to-adult survival at Bonneville (PIT tags) and Roza (PIT and coded-wire tags) dams.

To estimate smolt-to-smolt survival by rearing treatment (OCT/SNT), acclimation location, and raceway, biologists PIT-tagged and adipose clipped the minimum number to determine statistically meaningful differences detected at CJMF and lower Columbia River projects. (OCT refers to hatchery optimum conventional treatment, and SNT refers to reared fish with semi-natural treatment.) The remaining fish will be adipose fin clipped and tagged with multiple body placement coded-wire tags (CWT) unique for rearing treatment, acclimation location, and raceway. Returning adults that are adipose clipped at Roza Dam broodstock collection facility will be interrogated using a hand-held CWT detector to determine the presence/absence of body tags. YN will recover CWT during spawning ground surveys. Biologists will use ANOVA (analysis of variance) to determine significant differences between groups for both smolt-to-smolt and smolt-to-adult survival.

4. Roza juvenile wild and hatchery spring chinook smolt PIT tagging

YN will capture and PIT tag wild and hatchery spring chinook to estimate wild and hatchery smolt-to-smolt survival to Chandler Juvenile Monitoring Facility and the lower Columbia River projects. The Roza canal fish bypass will be used to capture wild and hatchery spring chinook smolts.

5. Yakima River wild and hatchery salmonid survival and enumeration

YN is continuing baseline data collection at the Chandler Juvenile Monitoring Facility (CJMF). The baseline data collected at CJMF—stock composition of smolts, outmigration timing, egg-to-smolt and/or smolt-to-smolt survival rates, hatchery v. wild and hatchery optimum conventional treatment (OCT), reared fish-v-hatchery semi-natural treatment (SNT), reared fish survival rates (spring chinook), etc.— is essential in determining whether post-supplementation changes are consistent with increased natural production. This data can be gathered for all anadromous salmonids within the basin. Additionally at the facility, YN proposes to refine the process of estimating the number of outmigrating juveniles by removing or accounting for sources of bias and then adjusting historical estimates of juvenile outmigrants.

The methods to be used in estimating the number of juvenile outmigrants are: First, estimated fish passage will be based on the experimentally derived fish-entrainment relationship. A sub-sample of salmonid outmigrants will be bio-sampled on a daily basis and all PIT-tagged fish interrogated. Grit-marked coho and fall chinook will be interrogated by hand using a black-light room located at the facility. Second, replicate releases of tagged smolts will be used to make a series of entrainment rate estimates. The entrainment rate estimates will be used in concert with a suite of independent environmental variables to generate a multi-variate smolt passage relationship will be used to estimate future and historical passage estimates with confidence intervals. Hand held CWT detectors will test for collection efficiency bias caused by body-tagging fish with wire tags.

6.Yakima River fall chinook monitoring and evaluation

The purpose of this YN project is to determine optimal release timing to increase overall smolt and smolt-to-adult survival, and to investigate the general life history of wild Yakima River fall chinook.

The proposed methodology is as follows: Approximately 325,000 fall chinook smolts were produced from fish spawned during the fall of 1998. These smolts were divided into two groups. One group (162,500) will be reared using conventional methods using ambient river temperature incubation and rearing profiles. The other group (162,500) will use warmer well water to accelerate emergence and rearing and ultimately smoltification. Both groups of fish will be spawned, incubated and reared at the Prosser Hatchery. Fish from both groups will be 100% marked using ventral fin clips (pelvic fins), and approximately 2000 fish from each group will be PIT-tagged to evaluate survival and migration timing to the lower Columbia River. Smolt-to-adult survival will be estimated from adult returns at Prosser Dam using video counts. Statistical analyses utilized will be a student t-test. Water temperature within the mainstem Yakima River and fall chinook growth profiles were monitored in the spring of 2000 to help determine whether or not temperature may be limiting fall chinook production above Prosser Dam. Approximately 1000 PIT tagged Marion Drain hatchery fall chinook juveniles will be released to estimate survival from Marion Drain Hatchery to Chandler Juvenile Monitoring Facility and McNary Dam.

7. Yakima River coho optimal stock, temporal, and geographic study

The purpose for this YN project is to determine the optimal location, date, and stock of release to maximize the feasibility of coho re-introduction into the Yakima Basin, and to determine the spawning distribution of returning adults.

A nested factorial experimental design is used to test for survival differences between out-of-basin hatchery and Prosser Hatchery stocks, release locations (upper Yakima and Naches subbasins) and release dates (May 7 and May 31). A total of 485,000 and 15,000 smolts from outside the basin and Prosser Hatchery stocks respectively will be released in the upper Yakima and Naches subbasins (1,000,000 total). Each release date will have two replicates per subbasin (128,750 smolts per replicate). Within each replicate 2480 coho smolts will be PIT-tagged (1240 out-of-basin stock and Prosser Hatchery stock) to evaluate survival to CJMF and lower Columbia projects. Beginning in 2000 in addition to PIT tags to monitor juvenile survival, the project will use CWT to assess survival to returning adult at Prosser Dam. Approximately 121,250 out of basin smolts per replicate will be coded-wire tagged to monitor smolt-adult survival. The total release numbers however, will not change between years. CWT placement will be the snout position, and fish will not be adipose fin-clipped, marks will be recovered during broodstock collection. Statistical analysis for this experiment will be ANOVA (analysis of variance) and multiple comparison tests. Coho spawning distribution will be assessed by radio tagging approximately 100 Yakima basin adults trapped at Prosser, Cowiche and Roza dams. Monitoring will include fixed and mobile telemetry gear.

8. Yakima spring chinook juvenile behavior

YN and WDFW will qualify and quantify behavioral differences between hatchery Yakima spring chinook rearing treatments and smolts, and to correlate those behaviors to smolt survival. Dominance relationships between different rearing treatments of spring chinook will be examined. This research will help managers understand if a juvenile hatchery spring chinook can be cultured to have minimal impact on wild fish.

YN will observe (direct and video) hatchery (OCT and SNT) and wild spring chinook collected at Roza and Prosser dams in a controlled environment that closely replicates natural environment. Response variables will include: water column position, position to overhead cover and substrate, preferential use of different cover types, latency to normalized behavior and feeding, time required to adopt wild behavior. Data analysis will probably involve principal component analysis and ANOVA.

WDFW will place OCT/SNIT fish in behavioral arenas at the Cle Elum Hatchery. Food acquisition, agonistic behavior, habitat use, and predator avoidance will be recorded and analyzed for the two treatment groups. Dominance will be attributed to fish with the most food and those that occupy the preferred location and/or initiate the most behavioral interactions.

9. Yakima spring chinook juvenile morphometric/coloration

One of the fundamental hypotheses for employing a SNT rearing treatment is to produce hatchery fish that are very similar to wild spring chinook with respect to morphometric/coloration. This activity will evaluate differences in morphometric/ coloration between the two rearing treatments employed for Yakima spring chinook.

YN and WDFW staff will photograph juvenile hatchery fish from the OCT and SNT raceways. Morphological measurements will be collected from the photographs and used to characterize the body shape of each treatment group. Statistical analysis will consist of linear discriminant and principle component analysis. Photographs taken just prior to release will be analyzed to determine whether there are significant differences in body coloration between OCT and SNT fish.

10. Yakima spring chinook smolt physiology

NMFS physiological studies are comparing smolt readiness over time between hatchery OCT, SNT, and wild spring chinook smolts. From 1998 to the present, NMFS biologists (BPA project #199202200) have been conducting research to characterize the physiological development of the first three brood years (BY 97, 98, 99) of hatchery spring chinook salmon produced at the Cle Elum Supplementation and Research Facility under different rearing strategies. (See “Physiological Assessment of Wild and Hatchery Spring Chinook” in Existing and Past Efforts and “Spring Chinook” in Artificial Production.)

Blood samples are collected at the time of release and also on a regular basis at Roza and Prosser Dams throughout the smolt outmigration period. Response variables will include: thyroxin, insulin-like hormone, % lipids, and growth and condition factors. Statistical analysis will include ANOVA.

The physiology of these hatchery fish is being compared with physiological profiles for wild spring chinook compiled by Beckman et al. (2000) and with data from co-migrating wild fish collected at Roza, Prosser, and John Day Dams.

11. Adult salmonid enumeration at Prosser Dam

YN estimates the total number of adult salmonids returning to the Yakima Basin by species (spring and fall chinook, coho and steelhead), including the estimated return of externally marked fish (i.e., CWT) In addition, biotic and abiotic data is recorded for each fish run. Monitoring is accomplished through use of time-lapse video recorders and a video camera located at each of the three fishways. The videotapes are played back and various types of information are recorded for each fish that passes.

12. Adult salmonid enumeration and broodstock collection at Roza and Cowiche dams

YN estimates the total number of adult salmonids returning to the upper Yakima basin (Roza) for spring chinook, steelhead and coho, and the total number of adult coho returning to the Naches subbasin. This includes the estimated return of externally marked fish (i.e., CWT).

From September 15 to March 31, monitoring is accomplished through use of video monitoring. From April 1 to September 14, adult enumeration (steelhead and spring chinook) and broodstock collection (spring chinook only) is accomplished by operation of the adult fish trap at Roza Dam. All adipose-clipped spring chinook will be interrogated with a hand-held coded-wire tag detector for the presence of body tags that identify each release rearing (OCT/SNY), acclimation location and raceway group. Potentially, coho broodstock collection will occur at Roza Dam. Also, from September 15, through December 31, coho enumeration is accomplished at Cowiche Dam through use of video monitoring.

13. Spawning ground surveys (redd counts)

YN biologists enumerates the temporal, spatial distribution of redd deposition in the Yakima basin for spring chinook, Marion Drain fall chinook, coho and Satus/Toppenish steelhead. They also collect biological information from spawned out carcasses. Regular foot and/or boat surveys are conducted within the established geographic range for each species (this is increasing for coho as acclimation sites are located upriver and as the run increases in size). Redds are individually marked during each survey and carcasses are sampled to collect- egg retention, scale sample, sex, body length and to check for possible experimental marks.

14. Yakima spring chinook spawning behavior observations

Through detailed observations, WDFW scientists will be able to characterize typical spring chinook reproductive behavior to serve as a baseline to compare with hatchery fish behavior when it is ultimately analyzed.

In this early phase, prior to the expected return of hatchery-produced adults in 2001, field activities will focus on observation and analysis of natural spawning spring chinook adults in the upper Yakima and Naches rivers. Such behavioral observations of naturally spawning fish will facilitate power analyses on eventual comparisons between wild and hatchery fish by assessing how much variation is natural in the frequency and execution of certain behaviors and from year to year. In addition, the presence and behavior of precocial males associated with spawning females will be recorded. Results will be reported and submitted to a peer-reviewed journal. Observations will be recorded on audiotape and underwater video recordings.

15. Yakima spring chinook residuals/precocials studies

WDFW is estimating the abundance of residual and precocial hatchery and wild spring chinook salmon. To estimate residuals, snorkeling will be conducted in index areas to determine the abundance of spring chinook salmon that did not migrate as age 1+ smolts. In addition, some of these fish will be examined to determine if their gonads are developing prematurely. To assess whether supplementation strategies increase the abundance of precocially mature spring chinook salmon, snorkelers will count the number of precocial spring chinook salmon on active spring chinook salmon redds within index areas.

16. Yakima River relative hatchery/wild spring chinook reproductive success

One of the major questions being raised about salmonid restoration and supplementation programs is whether hatchery produced adults can successfully reproduce under wild conditions. This activity is designed to directly investigate and answer that question. In 2000, YN and WDFW constructed and "debugged" an artificial spawning channel to measure baseline wild reproductive behavior. In the future we will compare the behavior of naturally spawning individuals in the wild to behavior observed in the channel and indicate whether there is any significant "channel effect" impacting wild behavior.

DNA-typed wild spring chinook adults and jacks collected at Roza Dam and precocial males will be tagged with individually numbered disk-tags and placed into Cle Elum spawning channel. Phenotypic and morphological traits will be collected and ethological characterizations of the reproductive behavior of individual fish will be made. Reproductive success— the estimated number of progeny produced by each male and female—will be estimated by trapping post-emergent fry and identifying their parentage via DNA analysis. Statistical analysis will be by ANOVA.Visual observations will be recorded on audiotape and, where possible, underwater video recordings will also be made.

17. Yakima spring chinook gamete quality monitoring

WDFW biologists will characterize the upper Yakima spring chinook population by age class in terms of fecundity, egg size, total reproductive effort, female size (weight and length) v. fecundity relationship, fertility, in-hatchery egg-to-fry survival, occurrence of monstrosities, emergence patterns, and fry size v. female size relationship.

Adult female traits and egg size will be measured at the time of spawning. Fertility, in-hatchery mortality and monstrosities will be measured on a subsample of eggs collected from individual females and incubated in separate isolettes. Emergence timing of fry from individual females will be measured by placing eyed eggs into incubation containers with substrate and an outlet with a catch basin. Fry will be counted as they volitionally exit the rearing containers on a daily basis. Hatchery returns will be sampled in the same manner in 2001 and compared to their wild counterparts. Statistical analysis will include ANOVA, ANCOVA (analysis of covariance) and linear regression.

18. Scale analysis

From scale analyses, YN plans to determine age and stock composition of juvenile and adult salmonid stocks in the Yakima basin. YN uses scale analysis to achieve this task. Genetic data needs to be analyzed on a brood year basis, and the age structure of the population is itself an important genetic characteristic. Thus, aging the broodstock scales samples collected at the time of trapping will provide a baseline and be used to augment the biochemical genetic data. YN also will use scale analysis to determine the proportion of hatchery v. wild smolt and adult Yakima coho production. Juvenile coho scales will be randomly collected at CJMF. Estimates of the proportion of hatchery and wild smolts will be applied to the estimated smolt outmigration. Adult coho scales will be collected at the broodstock collection facilities to estimate the proportion of hatchery/wild escapement. Estimates of the proportion of hatchery and wild adults will be applied to estimated adult returns.

19. Fish health monitoring

This activity, which is performed by USFWS, has two objectives: to monitor the physiological health and disease status of hatchery fish in the Yakima basin (both juveniles and adult broodstock) and to establish a baseline data set describing existing levels of pathogens in wild spring chinook prior to introduction of hatchery fish.

Approximately 200 Cle Elum hatchery juveniles will be sacrificed at biweekly intervals and examined for disease and incidence of pathogens. All adult broodstock will also be examined for pathogens upon spawning at the hatchery. The work will follow USFWS protocols and laboratory analyses will be conducted at a USFWS fish health laboratory. In addition, approximately 200 wild spring chinook smolts will be fully screened according to standard USFWS protocols at a USFWS fish health lab. This work will use fish already collected for ongoing Chandler Smolt Trap calibration work (electrophoretic stock identification).

20. Habitat monitoring flights and ground truthing

YN proposes to measure a number of environmental variables in the Yakima basin by analyzing data extracted from periodic aerial videos. The habitat conditions (e.g. water temperature, large woody debris, pool/riffle ratio, side channel abundance, substrate composition) from the video tape will be checked by "ground truthing" —dispatching crews of technicians to specific areas to verify that conditions are in fact as they appear on tape.

21. Trophic enhancement research

WDFW is studying the use of fish carcasses to "fertilize" streams, which are currently deficient in nutrients. (See Limiting Factors.) After fall chinook carcasses from the Priest Rapids Hatchery are "outplanted" in study streams, biologists measures carcass decay timing, invertebrate utilization, juvenile fish utilization, and growth and survival rates of juvenile fish among other parameters. A major concern regarding this activity is disease transmission. Accordingly, WDFW will sterilize carcasses, perhaps using gamma ray irradiation.

22. Sediment impacts on habitat

YN is monitoring stream sediment loads associated with the operation of dams and other anthropogenic factors such as logging, agriculture and road building that can increase sediment loads in streams utilized by all salmonids in the Yakima subbasins. (Excessive sediment loads can play a critical role in egg-to-fry survival, and can depress survival and productivity of many other life stages of salmonids.) Representative gravel samples will be collected from throughout an impacted reach. Each sample will be analyzed to estimate the percentage of fines or small particles present. Then Timber/Fish/Wildlife guidelines on sediments will be used to specify the impacts estimated sedimentation levels have had on salmonid egg-to-smolt survival. These impacts will be incorporated in analyses of "extrinsic" effects on natural production.

23. Manastash Creek Carcass Enhancement

Post-spawned spring chinook salmon from the Cle Elum hatchery will be stocked into each of two, 1 km reaches in Manastash Creek to determine the impacts to resident salmonids. Abundance and size structure of fish will be compared in sites that were stocked with salmon carcasses and those that were not. Taneum Creek will serve as a control stream.

24. Predator avoidance training

This activity is being conducted because hatchery fish have been shown to be more susceptible to predation than wild counterparts and it is suggested that hatchery fish lack skills required to avoid predators (Wiley et al. 1993; Olla et al. 1994; Maynard et al. 1995). WDFW' s predator avoidance training will introduce a hungry common merganser in a cage submerged in a raceway 3 times a week for 3 weeks prior to release. Upon release, the predator will be allowed to feed for 30 minutes. Coho will be PIT-tagged and assigned to control and treatment groups. Survival of both groups will be estimated at CJMF and McNary and John Day dams.

Harvest – YKFP

The overall harvest-monitoring objective is to develop methods for detecting increases in catch of YKFP target stocks.

1. Out-of-basin harvest monitoring

YN is developing a database to track the contribution of target stocks to out-of-basin fisheries. To estimate the harvest of target stocks, YN coordinates with WDFW, Oregon Department of Fish and Wildlife, USFWS, Columbia River Inter-Tribal Fish Commission and other management agencies responsible for harvest.

2.Yakima subbasin harvest monitoring

YN is developing a database to track the contribution of target stocks to Yakima basin fisheries. YN technicians will monitor tribal subsistence and sport fisheries on Yakima rivers at designated locations. Fish will be interrogated for various marks. This information will be used along with other adult contribution data such as broodstock, dam counts and spawner ground surveys to determine overall project success.

Genetics -YKFP

The overall objective is to develop methods of detecting significant PAPS (pre- and post-study) genetic changes in extinction risk, within-stock genetic variability, between-stock genetic variability and domestication selection.

1. Population viability analysis for all YKFP target stocks

WDFW is developing population viability analysis techniques for monitoring extinction risk of all YKFP target stocks. Existing stochastic supplementation dynamics models (including log-normal variability functions) already developed for the project (Busack and Knudsen, pers. comm.) will be refined to incorporate stock-specific demographic and environmental data.

2. Allozyme/DNA data collection and analysis

To augment the allozyme-related baseline data of all Yakima broodstock, WDFW will make a full baseline-level screening (approx 60 loci) of the broodstock. This will serve as baseline from which to monitor changes to allow examination of impacts on within- and between -population genetic variability. DNA data collection will probably be (depending on impending developments in technique) a nine-locus screening of the broodstock to serve as baseline from which to monitor changes.

The allozyme method involves tissues from chinook spawners (about 220 fish) will be analyzed according to standard WDFW protocol at the WDFW Genetics Lab. These data will also be compared to the four years of prefacility data collected by WDFW to monitor changes that have taken place in the five years since the prefacility data were collected, and to estimate effective size of the population. Researchers plan to do this annually through the first brood cycle, and then probably not again until the third or fourth generation of the operation. There is a good possibility that DNA data will totally supplant allozyme work in time and become useful in a wide variety of monitoring needs. The DNA method involves tissues from chinook spawners (about 220 fish) will be analyzed according to protocols developed by Dr. Paul Bentzen and colleagues at the University of Washington. The work will be done either at the University of Washington or at the WDFW Genetics Lab. WDFW scientists plan to do this annually at least through the first brood cycle, and then also analyze returning adults. This will give us a mating-by-mating measure of reproductive success and allow very precise estimation of effective population size.

3. Stray recovery on Naches and American River spawning grounds

The purpose of this WDFW activity is to determine the extent of gene flow from the supplemented Upper Yakima stock into the Naches and American River stocks. Upper Yakima fish on the American and Naches spawning grounds will be counted during normal spawning ground surveys and compared to the total run to estimate the maximum rate of gene flow.

4. Yakima spring chinook domestication

WDFW is developing a domestication selection study for Upper Yakima spring chinook that is sufficiently powerful to detect effects but also does not violate broodstock composition rules. The approach taken will probably involve measurement of a suite of traits in the progeny of hatchery x hatchery, wild x wild, and possibly hatchery x wild matings. Ideally these test groups will be compared in wild and hatchery environments. Size of study will be determined by power analysis and by modeling the genetic effects of modifying broodstock rules to allow hatchery fish to be used as broodstock. This work will be augmented by PAPS (pre- and post-study) comparisons of various traits.

Ecological Interactions -YKFP

The overall objective for these studies is to develop monitoring methods to determine if supplementation and enhancement efforts keep ecological interactions on non-target taxa of concern within prescribed limits, and to determine if ecological interactions limit supplementation or enhancement success.

1. Avian predation index

The loss of wild spring chinook salmon juveniles to various types of avian predators has long been suspected as a significant constraint on production and could limit the success of supplementation. The avian predator index will consist of two main components, an index of bird abundance and an index of consumption. An index will be calculated for each major bird predator.

Methods to determine the feasibility of accomplishing these two components were initially tested in 1998, and refined in 1999. Piscivorous birds will be counted on the ground using an inflatable raft, driftboat and jet sled, while aerial counts will be made using a fixed-wing aircraft. Shortly after or during bird censuses a consumption index will be developed. Observational and direct methods will be attempted to determine which methods are most appropriate for each bird species. Birds that swallow their prey above water (e.g., heron) might be evaluated using behavioral observations and those that swallow their prey underwater (e.g., merganser) might be evaluated using direct methods such as stomach content examination.

2. Fish predation index

YN & WDFW are indexing the mortality rate of upper Yakima spring chinook attributable to non-salmonid piscivorous fish in the lower Yakima. This index will be used to estimate the contribution of in-basin predation to fluctuations in hatchery and wild smolt-to-adult survival rates.

The densities of all major piscivorous fish species will be calculated during the smolt outmigration in representative reaches of the lower Yakima, and predator-specific smolt consumption data will be gathered in the same reaches. From this data, we will estimate both predator fish abundance and salmonid consumption. Population estimates will be determined using mark-recapture techniques, and consumption estimates will be made using the meal over-turn method

3. Coho/chinook predation study

YN will continue baseline monitoring of hatchery coho salmon smolt predation on fall chinook in the lower Yakima River. Up to 500 coho smolts will be collect throughout the out migration season at the CJMF for stomach content analysis. Coho salmon will be examined for the presence of fall chinook remains and the length at time of ingestion will be estimated for all fish prey items. Length frequency distributions of coho prey items will be compared to length frequency distributions of wild fall chinook in the Yakima River during the coho migration season collected via beach seining

4. Indirect Predation

The release of hatchery salmonids may enhance or decrease the survival of wild salmonid smolts by altering the functional or numerical response of predators. For example, predators may increase consumption of wild fish by switching prey preferences from invertebrates to fish, or may be attracted to areas where hatchery fish are released. Conversely, large numbers of hatchery fish may confuse or satiate predators resulting in enhanced survival of wild fish.

To investigate this interaction, YN will compare survival rates of PIT-tagged wild salmonid smolts in the presence and absence of large releases of hatchery coho or fall chinook salmon. Statistical analysis will include regression techniques. Other covariates in this analysis will include environmental condition (discharge, temperature, turbidity, and fish predator abundance).

5. Yakima River spring chinook competition/prey index

The abundance of prey may limit the number of spring chinook salmon juveniles that can be produced in the upper Yakima basin. For example, spring chinook salmon may compete with one another for the limited amount of food, which may result in density dependent survival. WDFW researchers will monitor stomach fullness of spring chinook salmon parr during the summer and fall in three index areas over time. Stomach fullness will be calculated by dividing the dry weight of the stomach contents by the maximum stomach weight specific to body length. Full stomachs will suggest that plenty of food is available and that it is not currently limiting spring chinook salmon production.

6. Upper Yakima spring chinook NTTOC monitoring

The purpose of this YN and WDFW research is to determine if the spring chinook supplementation program is impacting the abundance, distribution, or size structure of non-target taxa of concern (NTTOC). Scientists will compare pre- and post- supplementation data to determine potential impacts. Field efforts will include backpack and drift boat electrofishing, smolt counts at CJMF, and snorkeling. YN and WDFW will use status (abundance, size structure, and distribution) monitoring, interactions index monitoring, and interactions experiments to evaluate changes for 16 NTTOC.

7. Pathogen sampling

To determine if supplementation increases the incidence of pathogens, WDFW will establish a baseline data set describing existing levels of pathogens in wild spring chinook prior to introduction of hatchery fish. Biologists collected approximately 200 wild spring chinook smolts at CJMF throughout the migration period and later examined for fish pathogens using standard USFWS protocols at a USFWS fish health laboratory to calculate a fish pathogen index.

Fall Chinook Spawning Surveys

In 1998, WDFW received funding from Pacific Salmon Commission (PSC) related to implementation of the 1996 United States Letter of Agreement to conduct fall chinook spawning/carcass surveys in the lower Yakima River. These surveys were conducted in 1998 and 1999 (Watson and LaRiviere 1999; Watson and Cummins 2000). Again in 2000 WDFW conducted surveys but without funding from the Chinook Technical Committee. WDFW will conduct tall salmon spawning surveys again in 2001.

Salmon Creel Census

WDFW conducts creel surveys for fall and spring sport salmon seasons in the mainstem Yakima River to estimate harvest. Watson and Cummins (2000) reported methods and results of 1999 fall salmon creel census. Incidental harvest/catch and release of other species, including ESA listed steelhead is monitored during salmon creel census.

Wasteway Surveys

WDFW, in cooperation with the Roza-Sunnyside Board of Joint Control conducted electrofishing surveys to determine fish species inhabiting Snipes, Spring, Sulpher and Granger Creek Wasteways and drains flowing into those wasteways in 2000. Additional surveys are planned for 200.

Fish Distribution Inventories

Fish distribution inventories have been ongoing in the Cle Elum Ranger District using snorkeling and electro-shocking. The emphasis has been on bull trout distribution.

Steelhead Kelt Reconditioning

In 1999 the Yakama Nation initiated a steelhead kelt reconditioning feasibility program to determine if spawned out steelhead (kelts) could be reconditioned in fresh water. The objectives were to determine if the kelts would survive; if they would develop new gametes; and if they would spawn naturally when released.

In 2000 the Yakama Nation collected 512 steelhead kelts (April, May and June) on the smolt separator at the chandler juvenile evaluation facility (CJEF), and reared them in circular raceways. Of the 512 kelts collected, 90 (17.6%) were released in mid-December to spawn naturally. Although 1/4 of the kelts were lost in July when flow was interrupted to one of the four tanks, most of the non-surviving kelts starved because they never started feeding. The kelts responded well to freeze-dried krill when it was tried in July, so krill will be tested as a starter feed in 2001. In general, more tank capacity and more time to identify and care for non-feeding fish are needed to improve our reconditioning rate.

Females responded better to reconditioning than males and accounted for 86 (96.6%) of the 90 fish released. Females were about 86% of the kelts collected.

Ultrasound examinations revealed that only 57% of the 90 reconditioned kelts released were rematuring. The non-maturing fish were primarily those that had gained the least weight. Most (66%) of the immatures actually weighed less at release than when they arrived (and half had shrunk in length, incidentally). Hence, the 51 "re-spawners" (kelts that had both reconditioned and rematured) were 10% of the kelts collected, which still exceeds the 1.6% natural rate of repeat spawning documented in the Yakima River.

YN is now radio-tracking the released kelts. Of 20 fish released 70 miles downstream in McNary reservoir, 5 are known to have homed back up past Prosser (where they had been collected) by Jan. 30. Another 41 radio-tagged kelts were released upstream of Prosser, and the YN is now following their movement into Satus Cr. and the upper Yakima.

The NPPC approved full funding for this program in 2001, including more intensive care and feeding of the Prosser kelts. Dr. Ann Gannam, fish nutritionist at USFWS Abernathy Fish Technology Center, will help develop and test starter diets and maintenance/growth diets for steelhead kelts. A larger steelhead run and lower spring runoff suggests that more than 1,000 Yakima R. kelts (all wild, ESA threatened) could be collected at the juvenile migrant fish facility in Prosser in the spring of 2001.

Resident Fish

Bull Trout

Following standard protocol (Bonar et al. 1997) WDFW monitors the nine Yakima subbasin bull trout stocks by conducting annual spawning surveys in September and October. Spawning surveys and other monitoring is conducted with the assistance from U. S. Forest Service, U. S. Fish and Wildlife Service, Central Washington University, Yakama Nation, and Bureau of Reclamation. Spawning surveys were conducted on 22 streams in 2000.

In addition, Dr. Paul James, CWU, and his graduate students have and continue to conduct bull trout studies in the Yakima subbasin. Snorkel and electro-shocking surveys are conducted to determine presence/absence in waters where the presence of bull trout has not been confirmed. WDFW and CWU have working on a cooperative project to monitor the migrational characteristics of the bull trout populations in Rimrock and Bumping Lakes. CWU is the primary lead on monitoring fish traps on Indian Creek and the S.F. Tieton River (Rimrock Lake stock) and on Deep Creek (Bumping Lake stock). Migrating adfluvial bull trout area captured during their downstream (post spawning) migration. Fish are tagged with individually numbered spaghetti tags, sex, length/weight data is recorded as well as a scale sample for aging and a tissue sample for DNA analysis. Research has been on-going for 4-5 years and was expanded to include tributaries of Kachess and Kacheelus Lakes in 1999. The project is funded by the Bureau of Reclamation (BOR), who regulates the water in these large irrigation storage reservoirs.

Resident Fish Surveys

WDFW conducts electrofishing, trap net, gillnet, hook and line and snorkel surveys in lakes and streams to determine species presence/absence and to monitor and evaluate management programs. Stream surveys are generally done with electroshocking or snorkel gear.

The Washington Department of Fish and Wildlife’s Warmwater Gamefish Enhancement Program Warmwater Research Team, in cooperation with WDFW District Fish Biologists monitor warmwater fish populations in Yakima Subbasin lakes and ponds using standardized biological sampling methods to determine the best management strategies to enhance fishing in these waters. Research, funded by WDFW, is focused on determining how to enhance warmwater fishing without adversely impacting native fish and wildlife populations.

Habitat

Benthic Index of Biotic Integrity

In 2000 Washington Trout initiated the first of four years of sampling of benthic invertebrates in tributary and mainstem reaches of the Yakima and Naches rivers to develop a Benthic Index of Biotic Integrity (B-IBI) for the Basin, which will serve as a cost-effective monitoring tool for the evaluation of point and non-point land use impacts on aquatic health.

Floodplain Gravel Mining Study

The Yakima River Floodplain is one of the most heavily mined floodplains in Washington State. Resource managers from Washington State Departments of Fish and Wildlife, Ecology and Natural Resources, Yakima County and the Yakama Nation have secured funding from the state Centennial Clean Water Fund and the Salmon Recovery Board to study the ecology of morphology of floodplain gravel pits and the affected riverine community. The goal of the Yakima River Floodplain Mining Study is to determine the degree of impacts that floodplain mines have on water quality and riparian ecology. The study will have six distinct areas of investigation that will be integrated to determine impacts related to floodplain gravel mining:

- A literature and research compilation will be put together to document past work and information gaps.
- A hydrologic model will be developed to evaluate gravel pit impacts to river and floodplain hydrology.
- A temperature and dissolved oxygen monitoring program will involve monitoring upstream, down stream and in the floodplain gravel pits.
- A geomorphology and pit lake bathymetry study will be conducted to provide the physical setting and aid in data integration and analysis.
- A benthic macroinvertebrate biological assessment will be conducted in relation to the river health and the floodplain gravel pits.
- Fish assemblage studies upstream, downstream and in the floodplain gravel pits will be conducted.

Publication of a final report can then be used by industry and permitting agencies when evaluating existing or future floodplain gravel pits. The information from these investigations will also be used to create a database that all study partners can use for further investigations and GIS mapping.

Naches Basin Carcass Enhancement

Fall chinook carcasses from Priest Rapids Hatchery are stocked into the Naches Basin during the fall. There is little if any direct evaluation of impacts, however we should be able to examine adult-smolt success for years where genetic sampling is done at Chandler (e.g., 1998-present).

Salmon Carcass Analogs

The benefits that marine derived nutrients from adult salmon carcasses provide to juvenile salmonids are increasingly being recognized. Current estimates suggest that only 6-7% of marine-derived nitrogen and phosphorous that were historically available to salmonids in the Pacific Northwest are currently available. As discussed in Limiting Factors, food constraints may be a major deterrent to salmonid restoration.

A variety of methods have been proposed to offset this nutrient deficit including: allowing greater salmon spawning escapement, stocking hatchery salmon carcasses, and stocking inorganic nutrients. However, each of these methods has some ecological or socio-economic shortcoming. WDFW researchers intend to overcome many of these shortcomings by making a pathogen-free product that simulates a salmon carcass (analog). Abundant sources of marine derived nutrients are available such as fish offal from commercial fishing and salmon carcasses from hatcheries. However, a method for recycling these nutrients into a pathogen free analog that degrades at a similar rate as a natural salmon carcass has never been developed. Researchers propose to 1) develop a salmon carcass analog that will increase the food available to salmonids, 2) determine the pathways that salmonids use to acquire food from analogs, and 3) determine the benefits to salmonids and the potential for application to salmonid restoration.

Researchers intend to use a before and after control-impact-paired design in six tributaries in the upper Yakima basin (as well as six streams each in the Klickitat and Salmon river basins) to determine the utility of stocking carcass analogs. Each of these basins has chronically low numbers of naturally produced anadromous salmonids and many indications that low food abundance is a factor limiting growth.

"Reaches Study"

As part of the Yakima River Basin Water Enhancement Program, the Yakama Nation and the Bureau of Reclamation have contracted with the University of Montana and Central Washington University to assess surface and groundwater interactions in relation to aquatic ecosystems and salmon habitat restoration in six reaches of the Yakima Basin. The study will demonstrate the extent of biophysical disconnection of the river and its key floodplain reaches. The study will identify priority reaches and recommend actions to maintain or restore the environmental integrity of the most sensitive areas of the river basins.

Non-storage Study

Following consultation with the State of Washington, tributary water right owners, and the Yakama Nation, a Yakima River Basin Water Enhancement study will be conducted on non-storage items that can be implemented to enhance water supplies for fish and wildlife and irrigation in Taneum Creek. The Bureau of Reclamation seeks to partner with the Yakama Nation on a Taneum Creek steelhead supplementation effort. Other tributaries will be addressed as funding allows.

Fine Sediment Monitoring

Cle Elum Ranger District has been monitoring fine sediment percentages use the TFW methodology since 1991. This has not been an annual program so there are some gaps in years when data was not collected.

Water Temperature Monitoring

The Cle Elum Ranger District has conducted water temperature monitoring on streams throughout the Cle Elum District for the past several years. Beginning in 2000, district staff paired some water thermographs with air temperature thermographs. This procedure will be continued in the on-going temperature monitoring program.

WDFW Vegetation Monitoring

Habitat evaluation procedures (HEP) will be conducted by WDFW Wildlife Area staff, Vegetation Management Team personnel, and volunteers every five years to monitor general habitat trends. At least two baseline transects will be replicated in each cover type for each area evaluated. Areas will be selected on the basis of differences in cover type, management history, and current management/restoration protocols. Data on shrub and herbaceous cover (Daubenmire 1970), visual obstruction (Robel et al. 1970), and species composition will be systematically collected using standard techniques. HEP surveys will be conducted within the same general time frame and location as the original baseline transects to ensure similar plant phenology. All transects will be documented with standard photographs.

Substantial areas of noxious weeds will be mapped and monitored every two years. Standard and periodic photographs will be taken at each area monitored. Site specific enhancement/maintenance monitoring will be done with similar techniques, but with more flexibility in periodicity (every 1 to 5 years). All techniques will be designed to be rigorous under field conditions, to produce data that is statistically sound when analyzed, and to document results that are potentially useful with regard to future management opportunities

Monitoring, such as the vegetation monitoring program described above, is an important component of adaptive management. Adaptive management consists of 4 basic steps: 1) resource objectives are developed to describe the desired condition; 2) management is designed to meet the objectives; 3) the response of the resource is monitored to determine if the management objective has been met; and 4) management is adapted (changed) if objectives are not reached. Monitoring provides the link between objectives and adaptive management**.**

Wildlife

Monitoring Activities within Wenas Wildlife Area (WWA)

Monitoring includes both vegetation and wildlife. In addition, WDFW personnel and/or volunteers conduct neo-tropical bird surveys, sage grouse survey, mule deer/elk production counts, and hunter harvest surveys.

WWA, a BPA-funded mitigation project, provides habitat for both T&E species and Priority Habitat Species (PHS) and is an important link in WDFW’s ongoing efforts to reverse downward population trends in shrub-steppe obligate wildlife species, such as sage grouse, and to improve water quality for both anadromous and resident fish alike.

Yakama Nation Wetlands and Riparian Restoration Project

1. Habitat Monitoring

In 1990 the Wildlife staff of the Yakama Nation developed a HEP methodology which can be used to efficiently measure large acreages (Bich et. al 1991). These methods were applied to a 55,000 acre area along the floodplain habitats in the valley portion of the Yakama Reservation. The results of this effort led to one of the first large-scale wetlands and riparian restoration projects funded under the Northwest Power Act.

In 1999 this methodology was used to measure the success of the restoration efforts conducted since 1991 (Raedeke, 2000). The results are summarized in Tables 55 and 56. This field exercise also included a comparison of the YN HEP methods to a Delphi approach (Raedeke 2000) and to an intensive transect approach (WDFW 1997). The results showed the YN method to require less time, training and field effort per unit area than did the other two methods. Due to the much larger number of sample plots possible under the YN methodology, it was also judged to provide the most reliable HEP results. (BPA No. 9206200)

2. Population Monitoring

To date, most wildlife population monitoring activities involve game species production and wintering estimates. These population monitoring efforts, even when combined with the

HEP analysis, do not adequately measure the actual effects on wildlife abundance and diversity on the restoration sites. To address this problem, a report to guide the further monitoring efforts was developed (Millspaugh and Skalski 1999). This report recommends 1) a monitoring program based on plans with clear objectives, 2) that monitoring be conducted before and after restoration actions are performed, and 3) that wildlife response be measured at local and regional scales. Sampling considerations are described along with potential response variables. Finally, three techniques designed to link habitat activities with wildlife response are described. These monitoring techniques are currently being incorporated into the project. (BPA No. 9206200)

Table 56. 1999 HSI results for the Yakama Nation wetlands and riparian restoration project

All Areas

Average HSI scores using Yakama Method used in final HU calculations

Cover type	n	Calif. quail	Canada goose	Mallard	Sand-piper	Mink	Meadow-lark	Black-cap Chickadee	Warbler	Heron	Downy woodpecker
Forest	9		0.74			0.84		0.78		0.18	0.69
Shrub	8	1.00				0.74			0.56		
Herb	4	1.00	0.75	0.10							
SSG	14	0.98	0.82	0.36			0.22			0.23	
Ag-c/f	3	0.70								0.10	
Ag-p/f	18	0.99	0.75	0.35			0.43			0.25	
Lake	2		0.70	0.30						0.35	
Riverine	8					0.35				0.80	
POW	3		0.70	0.20						0.30	
PEM	10			0.64		0.64					
PUB	5		0.76		0.70					0.50	

Table 57. 1999 HU results for the Yakama Nation wetlands and riparian restoration project.

Cover type	Acres	Calif. quail	Canada goose	Mallard	Sand-piper	Mink	Meadow-lark	Black-cap Chickadee	Warbler	Heron	Downy woodpeck	Total HUs
Forest	923		683			775		720		166	637	2981
Shrub	1396	1396				1033			782			3211
Herb	742	742	557	74								1373
SSG	5105	5003	4186	1838			1123			1174		13324
Ag-c/f	1763	1234								176		1410
Ag-p/f	205	203	154	72			88			51		568
Lake	23		16	7						8		31
Riverine	205					72				164		236
POW	285		200	57						86		342
PEM	509			326		326						652
PUB	225		171		158					113		441
Total	11381	8578	5966	2373	158	2206	1211	720	782	1938	637	24568

Statement of Fish and Wildlife Needs

The following is a list of near-term fish and wildlife needs that take into account assessment information and management goals, objectives and strategies. Although a variety of agencies and organizations have cited many of the same needs, they are (will be) only described once. (Agencies and groups will not necessarily be identified in the final draft.)

Restore normative structure and function to aquatic and terrestrial habitat throughout the basin to the greatest degree practicable.

Restore/preserve floodplain connectivity

Wherever possible, historically unconfined, alluvial river reaches must be reconnected to the floodplain. This will entail removing or breaching dikes, constructing set-back levees, reconnecting cut-off side channels and sloughs to the river, and acquiring easements to and/or purchasing affected floodplain properties. Success in implementing this measure, in combination with restoring the riparian community, will go far toward alleviating perhaps the single greatest constraint on natural production in the Yakima today: a lack of habitat complexity and diversity.

Individual action items submitted by various contributing organizations and agencies that address this need include the following:

• Restore the productivity of floodplain properties in priority mainstem reaches.

• Reconnect tributaries to the mainstem Yakima and Naches River by restoring flows, and removing or modifying barriers. (NMFS)(YN)

• Many properties in the flood plain have been built upon since the flood of 1996. Acquiring available properties before any more structures are built is of great importance.

• Purchase private properties to reconnect the floodplain, and restore and protect riparian habitat and natural hydrologic regime.

• Acquire floodplain habitats along the mainstem Yakima and Naches Rivers. (YN)(NMFS)(WDFW)

Candidate parcels should include lands presently situated behind dikes where the attendant restoration plan includes breaching or retrofitting dikes to allow fish access.

(NMFS) Managers have identified numerous parcels for protection, including (Move list to Strategies)

1. Keechelus to Cle Elum Reach: Purchase of 670 acres at risk of conversion to mining or residential development. Estimated cost: $6,000,000
2. Cle Elum to Teanaway Reach: Purchase of 300 acres at risk of conversion to residential development or mining. Estimated cost: $1,500,000.
3. Ellensburg Reach: Purchase of 350 acres at risk of conversion to mining, residential or high-intensity recreational. Estimated cost: $2,100,000
4. Selah Reach: Purchase of 70 acres at risk of conversion to mining, residential or high-intensity recreational. Estimated cost: $350,000
5. Lower Naches Reach: Purchase of 200 acres at risk of conversion to residential or mining. Estimated cost: $700,000 (YN)

Restore normative flows.

This need has four general elements: 1) rectifying the non-normative hydrograph in the upper Yakima mainstem, which is characterized by diminished spring peak flows, elevated summer flows and diminished fall-winter flows. 2) Reducing the adverse impacts to the aquatic ecosystem associated with the river operation schemes known as flip-flop and mini-flip-flop. 3) Reducing adverse impacts to the aquatic ecosystem associated with non-normative flows in the lower Yakima, which are characterized by excessive short-term fluctuation and year-round sub-normative flows. 4) Taking appropriate, site-specific measures to reduce or eliminate the dewatering of various tributaries associated primarily with irrigation withdrawals.

Individual action items submitted by various contributing organizations and agencies that address this need include the following:
• Implement on-farm water conservation for mainstem diverters where saved water can be re-allocated to instream flows. (NMFS)
• If feasible, move the intake system for Kennewick Irrigation District from the Yakima River to the Columbia River (Kennewick Pump Exchange). (BOR)
• If feasible, buy out the Wapatox Power Plant to benefit salmon and steelhead by increasing instream flows in the lower Naches River. (BOR)
• Recommend alternatives for establishing more normative flow regimes in the Yakima core area. (WDFW)
• Evaluate management options for municipal aquifer and surface water withdrawals that would improve the timing of water extraction to minimize impacts on water supply.
• Create a water management tool (RiverWare/EDT link) to improve decision making related to minimizing impacts to the aquatic environment. (BOR)

Restore access to historical production areas to all life stages of resident and anadromous salmonids.

Upstream and downstream migration of salmon, steelhead and resident fish is blocked or impeded at numerous locations by diversion dams, culverts and other structures. In addition, irrigation withdrawals dewater certain tributaries to the extent that passage of all life stages is hindered or totally precluded. Resolution of this need will require actions such as: Installation, maintenance and evaluation of fishways and screens, installation or improvement of culverts, measures that make provision for sufficient instream flows for adult passage and juvenile rearing, and renovating existing fishways to reduce passage delays. Impaired homing of adult salmonids can also be considered an access issue. The homing of several species of anadromous salmonids in the Yakima Subbasin is impaired by false attraction to operations spills from irrigation canals carrying water from the upper basin. Other locations in the subbasin also present similar false attraction issues for different reasons.

Individual action items submitted by various contributing organizations and agencies that address this need include the following:
• Screen diversions from Yakima River tributaries. Priority should be placed on screens within stream reaches presently accessible to anadromous fish and proceed upstream in advance of passage projects as described above. (NMFS)(YN)
• Evaluate culvert modifications to determine if passage conditions have improved (PNNL)
• Identify and repair, or remove, or relocate roads and culverts that are susceptible to mass wasting and bank failures; that negatively impact riparian areas, and inhibit connectivity and natural stream functions in all fish-bearing watersheds. (WDFW)
• Continue monitoring new and existing fish passage facilities within the Yakima River basin to ensure that they are adequately protecting fish and are being operated and maintained to meet NMFS fish protection criteria. (PNNL)
• Properly screen all remaining major water diversions on Yakima River Basin tributaries where fish or habitat may be affected by diversions and barriers. This effort generally referred to as Phase III. USBOR led the Phase I and Phase II efforts to properly screen all major water diversions on the mainstem Yakima River and in some of the tributaries. Phase III continues this effort. Phase III collaborators include the USBOR, WDFW, Yakima

Nation, Conservation Districts (KCCD, NYCD), the KCWP and its members (Kittitas Reclamation District, Cascade Irrigation District, Ellensburg Water Company, Westside Irrigation Company, individual water rights holders and other water suppliers providing irrigation water for more than 90,000 acres in Kittitas County). In addition, individual diverters on tributaries and smaller irrigation entities will become involved as this process evolves. More than 50 individuals and irrigation entities have already stepped forward, indicating their desire to properly screen and provide for fish passage. (BOR) (YN) (WDFW) (Conservation Districts)

• Mitigate for the effects of barriers such as road culverts to both juvenile and adult anadromous and resident fishes. Existing culverts that block access to upstream rearing/spawning habitat need to be retrofitted to improve passage conditions (and those modifications should be evaluated in the field). (PNNL)

• Restore migratory access to the historic range of anadromous fishes through construction of fishways, screens, pumps and on-farm irrigation systems that will allow safe access to productive spawning and rearing habitats in key tributaries. (YN)

• Screen all water diversions and irrigation ditches which may create low water barriers and increase stranding of bull trout in the Yakima core area (e.g., Beck Diversion, John-Cox Ditch, Wapato Irrigation Project Diversion, Rattlesnake Creek, Teanaway River). (WDFW)

• Replace culverts that are passage impediments. Continue operation and maintenance of BOR owned and some BPA owned fish passage and protection facilities.

• Work with other entities to provide passage for anadromous fish in Yakima basin tributaries; identify fish barriers or unscreened diversions; and develop solutions that allow for fish passage. (BOR)

• Prevent fish mortalities, including of ESA-listed salmonids, caused by the Naches River Water Treatment Plant intake systems. (City of Yakima)

Restore normative water quality to basin streams.

Almost all classes of water quality parameters are impaired at some point in the Yakima Subbasin, especially in the lower reaches. Sediment loading is associated with logging, roads, mass wasting, reservoir operations, and agricultural practices. Thermal pollution is the result of a complex combination of non-normative factors including elimination of spring flooding, disconnection of the floodplain, a non-normative summertime hydrograph, water withdrawals, floodplain gravel mining, logging and riparian degradation, and various agricultural practices. Pesticide/herbicide contamination is primarily associated with sediment loading associated with agricultural practices. Directly or indirectly, most of the other impaired water quality parameters are associated with agricultural and urban runoff.

Individual action items submitted by various contributing organizations and agencies that address this need include the following:

• Improve water quality throughout the Subbasin by addressing each of the factors contributing to impaired water quality.

• Restore sloughs, ponds, and side channels within to restore natural ecological processes and habitat of the area and help reduce water temperatures.

• Assess the usefulness, cost, and feasibility of modifying the outlet works of all of the storage dams to provide enhanced water temperature control.

• Initiate a water quality monitoring program in the lower Yakima River below Kiona, where no monitoring is currently being conducted. (Tapteal)

• The impact of uncontrolled urban runoff to anadromous fish-bearing streams needs to be determined. (YN)

Restore normative ecological interactions among target species and aquatic communities in all portions of the basin.

Longstanding non-normative habitat conditions have unbalanced the fish communities in the Yakima Subbasin. There is evidence to suspect the following type of problems associated with an unbalanced ecosystem:

1) Excessive predation on juvenile salmonids exacerbated by high temperatures, introduction of exotic species and instream structures (dams and bypass outfalls) that increase the vulnerability of juveniles.
2) Possible constraints on fish and wildlife production attributable limited availability or accessibility of habitat and/or food.
3) Impaired production of fish and wildlife attributable to the scarcity or elimination of mutualists and/or keystone species. A very important mutualist to both fish and wildlife is the beaver and the habitat beaver populations create.
4) Possible constraints on fish and wildlife production associated with pathogens.

Restore and preserve riparian communities and normative watershed function.

Widespread riparian degradation has been one of the most significant factors in the decline of fish and wildlife populations in the Yakima Subbasin. Specific impacts of a degraded riparian corridor for fish include: lack of pools, poor gravel retention, increased water temperature, increased predation, and so on. Specific impacts on wildlife include impaired migration and elimination of breeding and rearing habitat for birds, mammals, reptiles and amphibians. Watershed function has been altered by logging and grazing practices. Runoff and infiltration has been altered by these activities to the degree that baseflows have been lowered, sediment loading has been increased, and channel stability decreased.

Individual action items submitted by various contributing organizations and agencies that address this need include the following:

• Develop and implement adaptive livestock grazing management plans which include performance standards and targets for habitat and water quality conditions that grazing practices must meet. Plans should address excluding grazing from fish spawning grounds during times of the year that spawning occurs (e.g. August-October). (WDFW)

• Purchase outright or purchase conservation easements for the establishment of riparian zones along anadromous- and other fish-bearing streams in the Yakima Basin. (NMFS) (YN) (WDFW)

• Improve habitat structure (i.e., riparian planting, instream structures) in irrigation return drains and wasteways accessible to anadromous fish. (NMFS)

• Make off-channel watering improvements through additional fencing and revegetation. (YN)

• Control noxious weeds especially along the lower Yakima River, especially within the Chamna Natural Preserve and replace exotic plants with native species (willows, roses, etc.) to restore wetland and riparian areas.

• Eliminate the disruption of fish habitat at the Fruitvale Irrigation Canal diversion site on the Naches River as currently occurs during annual in-river maintenance. (City of Yakima)

• More efficient conveyance and use of water withdrawn from the Naches River for the City of Yakima is needed. (City of Yakima)

Protection and restoration of native fish and wildlife populations by increasing or maintaining productivity.

The abundance and diversity of native fish and wildlife species is much reduced from historic levels. The resolution of the proceeding fish and wildlife habitat needs will substantially improve the productive capacity of the Yakima Subbasin. Until the habitat has been substantially restored, there is a need for artificial production to increase the productivity of existing populations of fish and wildlife. Artificial production is also essential to restore extirpated species to the Yakima Subbasin. Productivity can also be enhanced by increasing the survival of existing populations by educating the general public in life history, identification, and habitat needs for fish and wildlife populations. Productivity can also be increased by enforcement of fish, wildlife and habitat regulations.

Individual action items submitted by various contributing organizations and agencies that address this need include the following:

ANADROMOUS

- Continue using EDT model to determine stream reaches that have high value for protection and restoration in salmon recovery efforts. Use model to determine relative benefits of habitat restoration and supplementation for all species and stocks of salmonids.
- Continue research on Spring Chinook to determine if supplementation can increase natural production and harvest while maintaining genetic resources. Determine if new hatchery rearing techniques can improve the survival and fitness of supplemented fish.
- Determine the reproductive ecology and success of supplementation produced adults compared to naturally produced fish.
- Monitor genetic structure of supplemented salmonid stocks.
- Monitor the ecological interactions of supplementation fish within the natural ecosystem (competition, predation, predator avoidance, residualism and precocialism)
- Determine the feasibility of re-establishing a sustainable, naturally spawning coho population in the Yakima Subbasin with sufficient productivity to sustain a meaningful in-basin fishery in most years.
- Optimize production of naturalized populations of coho with respect to abundance and distribution.
- Minimize adverse impacts of reintroduced coho on other species.
- Establish a Yakima River coho stock with heritable life history traits adapted to the Yakima Subbasin.
- Determine the feasibility of supplementing the two stocks of fall chinook in the Yakima Subbasin.
- Refine the knowledge of genetic structure of steelhead and resident rainbow trout.
- Determine if steelhead kelt reconditioning can be used to increase natural production in the Yakima Subbasin.
- With the Yakama Nation, investigate the feasibility of steelhead supplementation in Taneum Creek. (BOR)
- Investigate the feasibility of reintroduction of summer chinook and sockeye salmon in the Yakima Subbasin.
- Continue spawning ground surveys for all salmonids.
- Continue estimating adult returns of all salmonids.

- Resolve uncertainties about the role conditions in the lower Yakima River play in the natural production of the basin's fall chinook salmon; that is, address subyearling fall chinook survival; assess the quantity and quality of fall spawning and rearing habitat below Prosser and elsewhere; estimate channel fish predation more precisely; understand life histories of channel catfish and other non-native predators; and evaluate costs and benefits of increasing connectivity of lower Yakima River to the mainstem Columbia River, which would increase potential fall chinook habitat. (PNNL)
- Continue monitoring the physiological development of Yakima hatchery spring chinook salmon to further evaluate and improve the ability of supplementation hatcheries to produce high quality smolts with morphological, physiological, behavioral, and life-history attributes similar to wild fish.
- Future studies should be conducted to more accurately determine the incidence of precocious male maturation in both wild and hatchery populations of Yakima spring chinook
- Future studies should be conducted at the Cle Elum Supplementation and Research facility to develop rearing strategies for controlling precocious male maturation in the hatchery population.
- At least three genetically distinct stocks of spring chinook salmon have been identified in the Yakima River. Increased levels of straying due to hatchery rearing or acclimation/release practices may have negative genetic and ecological impacts on existing wild populations. Future physiology studies of juvenile spring Chinook should incorporate assessment of imprinting by juveniles released from different acclimation sites and ultimately compare these data with patterns of homing displayed by returning adults.
- Obtain and utilize information from outside sources —with various state and federal agencies, other research programs, hatcheries, and university researchers—regarding environmental and harvest-related impacts on all anadromous salmonids occurring outside the Yakima basin. (YN)

BULL TROUT

Integration of data from BOR, CWU and WDFW, in conjunction with the UW Cooperative Unit, is needed to provide valuable information on the current status of bull trout and other resident fish populations, and to indicate limiting factors in the reservoirs of the Yakima River Basin. (Results from this study could then be applied to future fisheries management objectives for bull trout conservation or preservation elsewhere in the state or Pacific Northwest.) (WDFW)

- Identify and assess site-specific threats that are likely having a negative effect on the suitability of bull trout habitats used for spawning, rearing (adult and juvenile), migrating, and over-wintering. (WDFW)
- Investigate alternative means to reduce or eliminate the possibility of entrainment losses in the outlet works of all the storage dams. (WDFW)
- Investigate feasibility of providing fish passage at Keechelus, Kachess, Cle Elum, Bumping, and Rimrock Reservoirs, Clear Lake and Big Creek diversion dam. (WDFW)
- Evaluate reservoir operations as they relate to water level manipulations and provide recommendations to insure successful passage to and from natal streams for adfluvial bull trout populations. (WDFW)

- Assess effects of residential and shoreline/floodplain development in known bull trout habitat (e.g., Lower Little Creek and Naches River). (WDFW)
- Information regarding the lacustrine life-stage of bull trout is needed for all five basin reservoirs —Keechelus, Kachess, Cle Elum, Rimrock, and Bumping. (As discussed in Limiting Factors, fragmentation and isolation of bull trout populations or subpopulations occurred as a result of the construction of water storage dams in the Yakima subbasin.)
- Determine the status of kokanee (Oncorhynchus nerka) in the Keechelus, Kachess, Cle Elum, Rimrock, and Bumping lakes. As an important prey source for bull trout in other systems, kokanee abundance is correlated with bull trout recruitment (Beauchamp and VanTassell, in press).
- Supplement the Bureau of Reclamation's limnological surveys (water quality, primary production and zooplankton dynamics): survey the fish community and conduct diet analyses. Bioenergetic analysis may also be needed to estimate bull trout consumption demands on kokanee and kokanee consumption demands on the standing crop of zooplankton, thereby quantifying the important trophic linkages affecting this sensitive species.
- Evaluate bull trout hybridization with brook trout and presence and effects of viable hybrids.
- Conduct intensive bull trout distribution and spawning surveys in the North and Middle Fork Teanaway, Cle Elum River, American River, Yakima River between Easton and Keechelus Lake, Cowichee Creek and other areas. Continue to conduct bull trout spawning surveys.
- Collect and analyze physical, chemical, and biological information on reservoirs in the Yakima Subbasin. (See additional needs above under Resident Fish).
- Determine movement and seasonality of use of different habitat types of adult and sub-adult migratory bull trout with specific emphasis on the mainstem Yakima River.

OTHER RESIDENT FISH

- Inventory the distribution and status of westslope cutthroat, resident rainbow trout and other resident native fish species and to develop status reports similar to those developed for salmon, steelhead and bull trout in both streams and lakes, particularly alpine lakes.
- Determine the phenotypic and genotypic characteristics of progeny resulting from interbreeding between anadromous and resident forms of O. mykiss in the Yakima River basin. Additional genetic profiling of westslope cutthroat is needed (Trotter et al. 1999).
- Evaluate the impact of resident trout fisheries on anadromous fish, particularly ESA listed species such as steelhead and bull trout. Biologists need to evaluate the response of resident trout and anadromous fish populations to sport fishing regulations implemented since the late 1980's (WDFW 1984; Wright 1992). The impact of fish stocking practices, particularly downstream movement of fish from lakes and reservoirs is not known.
- All trophic levels in Keechelus, Kachess, Cle Elum, Rimrock, and Bumping lakes need to be studied in order to evaluate any bottom-up or top-down effects in the aquatic community.
- Assess the relative abundance, distribution and trophic interactions of the diverse fish assemblages in Keechelus, Kachess, Cle Elum, Rimrock and Bumping reservoirs.
- Little information exists on the limnology and fish populations of the Yakima River Basin reservoirs. Mongillo and Faulconer conducted a limnological and fish survey in

1980-81 for WDFW and Heibert a lower trophic and water quality survey in 1998-99 for BOR. Mongillo and Faulconer's study found all 5 reservoirs to be meso-oligotrophic to oligotrophic; however, the recent surveys by Heibert found the reservoirs to be ultra-oligotrophic. This difference could be due to the use of different lake classification indexes; however, if oligotrophication is occurring, then actions may be necessary to boost production back to a level which would maximize the spawning potential of the tributaries in each system.

- Monitor kokanee, burbot and lake trout fisheries to obtain harvest or catch rate data.
- All of these sport fish populations are self-sustaining, but recruitment, age structure and impacts of planktivory and piscivory have not yet been studied and need to be studied. (WDFW)
- Eliminate the stocking of brook trout in the Yakima core area. (WDFW)

Planning and Management

- Implement the recovery strategies identified here and in the U. S. Fish and Wildlife Recovery Plan, Mid-Columbia Recovery Unit Chapter, when it is completed (the plan is currently in working draft form). (WDFW)
- Creative cooperation among agencies and organizations is needed to be able to go beyond the minimum mandatory mitigation when opportunities arise to benefit fish and wildlife. (County of Yakima)
- Develop genetic management plan for reconnecting isolated populations in the Yakima core area. Establish genetic baselines for each local population. (WDFW)
- Ensure bull trout recovery strategies are included as part of, and coordinated with other recovery efforts and management plans. (WDFW)
- Develop, maintain, and support liberal year round bag limits on non-native predators in Yakima core area (e.g., lake trout, brown trout). (WDFW)
- Reduce numbers and distribution of brook trout brown trout population in the Yakima core area.

Fisheries

Data Management and Technical Support

- Dedicated biometrical support is required at YKFP facilities to track measures proposed in the monitoring plan that require power analyses to evaluate feasibility and sample size requirements and to develop experimental statistical designs and maintain quality control. (YN)
- During the pre-facility years of the YKFP project, a large amount of data was collected on the fish and physical habitat, and as the monitoring effort gets underway, much more will accumulate. These data need to be organized into databases for ease of access and protection and made available on the Internet and to the public. (YN)
- A data storage and retrieval system is needed for Yakima subbasin lake and stream survey data. (WDFW)
- Managers need to implement a partnership-based salmon and steelhead information system (such as the Salmon and Steelhead Inventory and Assessment Program) that characterizes freshwater and estuary habitat conditions and distribution of salmonid stocks in the Yakima Basin. There are four parts to the approach: (1) delineation of

watersheds into discrete stream segments, (2) identification of current and potential fish distribution, (3) quantification of obstructed and degraded habitat, and (4) quantification of historical habitat. It should support and link with GIS productivity modeling, including the Ecosystem Diagnosis and Treatment (EDT) model, Habitat Conservation Plans and numerous other studies including river modeling work by the BOR, and a number of other ongoing studies by CWU, BOR and others that use various types of imagery to quantify aquatic habitat. (WDFW/YN). An important corollary objective is the development of automated computer programs to integrate the tremendous amount of empirical habitat data in GIS format into the EDT model.
- Technical and data entry support is needed for the angler fish database information system (Fender and Hahn 1994). (WDFW)

Education and Training

- Educate anglers about bull trout identification, special regulations, and how to reduce hooking mortality of bull trout caught incidentally in recreational fisheries. Develop public information program on bull trout identification. (WDFW)
- Educate the public about the importance of the lower reaches of the river. While extensive money is being spent in the upper and middle part of the watershed, little attention is paid to the condition of these first 30 miles of river (heading upstream) that adult spawners must get through, where summer water temperatures frequently exceed 75F, flows are low, algae is significant, and where some fall chinook also spawn. (Tapteal).
- Educate the public on the history, the importance, and requirements of spawning habitat in the lower reaches of the Yakima River. Educate the public and private landowners about streambank protection and restoration along the lower Yakima River (Tapteal)
- Educate students about: the components of the environment and impacts of human interactions within natural systems, the ways in which social and natural systems are fundamental in supporting our lives, economy and emotional well being, the fact that individual decisions and actions effect the environment, the ways in which cooperative action can be used to maintain and enhance the environment.
- Educate the public about laws pertaining to protection of fish and wildlife and their habitats. (Tapteal Greenway)
- Educate the public on the need and options for effective streambank protection and habitat restoration. (Tapteal)
- Provide construction, transportation and maintenance worker training to help improve fish and wildlife habitat protection. (Yakima County)
- Educate Yakama Nation members in Fish Culture technology.

Enforcement

- Enforcement of surface water diversionary rights is needed to help improve instream flows within individual irrigation districts. (YN)
- Ensure compliance with existing harvest regulations and policies and target fish spawning and staging areas for enforcement.
- Enforce existing regulations and monitor effectiveness relative to timber harvest activities and minimum riparian buffers to improve stream function in all fish-bearing watersheds.

- Identify and close, or provide law enforcement, for roads that increase risk of poaching and fishing pressure, especially in fish spawning and staging areas.
- Enforce existing habitat protection standards and regulations.
- Ensure that residential, shoreline/floodplains developments in fish-bearing areas comply and with state, county, and tribal land management plans.
- Protect public properties from improper and destructive river access, four-wheeling in flooded areas and wetlands, and dumping on public lands. (Tapteal)
- Manage dispersed and developed camping to avoid impacts to fish spawning and rearing habitat. (WDFW)
- Protect streambeds, rivershore, and riparian and adjacent upland from motor vehicle damage. A sizable fraction of rivershore in Richland should be protected from access by motor vehicles. Segments of rivershore in Richland are completely denuded from people driving to the river's edge to party and sit on their tailgate while fishing.
- Proper parking areas and fishing access that afford habitat protection are needed.(Tapteal)
- Cities and county need to work together to strengthen shoreline codes and create larger setbacks.
- An examination of water withdrawals by rivershore properties is needed to determine if they are within the permitted allotments.
- An estimation of the cumulative withdrawal of rivershore properties is also needed.
- County health departments need to inspect existing and older septic systems within the floodplain to ensure they are working properly.
- Reduce angler pressure in areas where incidental mortality continues to be detrimental to recovery.
- Utilize innovative techniques such as seasonal or permanent road closures and establishment of conservation regulations or fisheries management policies for other fisheries whose popularity may result in increased bull trout by-catch. (WDFW)

Habitat

- Reconnect tributaries to the mainstem Yakima and Naches River by restoring flows, and removing or modifying barriers. (NMFS)
- Screen diversions from Yakima River tributaries. Priority should be placed on screens within stream reaches presently accessible to anadromous fish and proceed upstream in advance of passage projects as described above. (NMFS)
- Purchase outright or purchase conservation easements for the establishment riparian zones along anadromous- and other fish-bearing streams in the Yakima Basin. (NMFS) (YN) (WDFW)
- Implement on-farm water conservation for mainstem diverters where saved water can be re-allocated to instream flows. (NMFS)
- Improve habitat structure (i.e., riparian planting, instream structures) in irrigation return drains and wasteways accessible to anadromous fish. (NMFS)
- Many properties in the flood plain have been built upon since the flood of 1996. Acquiring available properties before any more structures are built is of great importance.
- Purchase private properties to reconnect the floodplain, and restore and protect riparian habitat and natural hydrologic regime.

- Acquire floodplain habitats along the mainstem Yakima and Naches Rivers. Candidate parcels should include lands presently situated behind dikes where the attendant restoration plan includes breaching or retrofitting dikes to allow fish access. (NMFS) Managers have identified numerous parcels for protection, including:
    1. Keechelus to Cle Elum Reach: Purchase of 670 acres at risk of conversion to mining or residential development. Estimated cost: $6,000,000
    2. Cle Elum to Teanaway Reach: Purchase of 300 acres at risk of conversion to residential development or mining. Estimated cost: $1,500,000.
    3. Ellensburg Reach: Purchase of 350 acres at risk of conversion to mining, residential or high-intensity recreational. Estimated cost: $2,100,000
    4. Selah Reach: Purchase of 70 acres at risk of conversion to mining, residential or high-intensity recreational. Estimated cost: $350,000
    5. Lower Naches Reach: Purchase of 200 acres at risk of conversion to residential or mining. Estimated cost: $700,000 (YN)
- Restore the productivity of floodplain properties in priority mainstem reaches.
- Make off-channel watering improvements through additional fencing and revegetation. (YN)
- If feasible, move the intake system for Kennewick Irrigation District from the Yakima River to the Columbia River (Kennewick Pump Exchange). (BOR)
- If feasible, buy out the Wapatox Power Plant to benefit salmon and steelhead by increasing instream flows in the lower Naches River. (BOR)
- Identify and repair, or remove, or relocate roads and culverts that are susceptible to mass wasting and bank failures; that negatively impact riparian areas, and inhibit connectivity and natural stream functions in all fish-bearing watersheds. (WDFW)
- Protect public properties from improper and destructive river access, four-wheeling in flooded areas and wetlands, and dumping on public lands. (Tapteal)
- Manage dispersed and developed camping to avoid impacts to fish spawning and rearing habitat. (WDFW)
- Recommend alternatives for establishing more normative flow regimes in the Yakima core area. (WDFW)
- Develop and implement adaptive livestock grazing management plans which include performance standards and targets for habitat and water quality conditions that grazing practices must meet. Plans should address excluding grazing from fish spawning grounds during times of the year that spawning occurs (e.g. August-October). (WDFW)
- Control noxious weeds especially along the lower Yakima River, especially within the Chamna Natural Preserve and replace exotic plants with native species (willows, roses, etc.) to restore wetland and riparian areas.
- Initiate a water quality monitoring program in the lower Yakima River below Kiona, where no monitoring is currently being conducted. (Tapteal)
- Protect streambeds, rivershore, and riparian and adjacent upland from motor vehicle damage. A sizable fraction of rivershore in Richland should be protected from access by motor vehicles. Segments of rivershore in Richland are completely denuded from people driving to the river's edge to party and sit on their tailgate while fishing.
- Proper parking areas and fishing access that afford habitat protection are needed. (Tapteal)

- Restore sloughs, ponds, and side channels within to restore natural ecological processes and habitat of the area and help reduce water temperatures.
- Cities and county need to work together to strengthen shoreline codes and create larger setbacks.
- An examination of water withdrawals by rivershore properties is needed to determine if they are within the permitted allotments.
- An estimation of the cumulative withdrawal of rivershore properties is also needed.
- County health departments need to inspect existing and older septic systems within the floodplain to ensure they are working properly.

Harvest

- Reduce angler pressure in areas where incidental mortality continues to be detrimental to recovery.
- Reduce angler pressure in areas where incidental mortality continues to be detrimental to recovery.
- Expand harvest opportunities for treaty Indian and sport fisheries inside and outside the Yakima Subbasin while meeting objectives for genetics, experimentation, natural production, and ecological interactions.
- Utilize innovative techniques such as seasonal or permanent road closures and establishment of conservation regulations or fisheries management policies for other fisheries whose popularity may result in increased bull trout by-catch. (WDFW)

Passage

- Continue monitoring new and existing fish passage facilities within the Yakima River basin to ensure that they are adequately protecting fish and are being operated and maintained to meet NMFS fish protection criteria. (PNNL)
- Properly screen all remaining major water diversions on Yakima River Basin tributaries where fish or habitat may be affected by diversions and barriers. This effort generally referred to as Phase III. USBOR led the Phase I and Phase II efforts to properly screen all major water diversions on the mainstem Yakima River and in some of the tributaries. Phase III continues this effort. Phase III collaborators include the USBOR, WDFW, Yakima Nation, Conservation Districts (KCCD, NYCD), the KCWP and its members (Kittitas Reclamation District, Cascade Irrigation District, Ellensburg Water Company, Westside Irrigation Company, individual water rights holders and other water suppliers providing irrigation water for more than 90,000 acres in Kittitas County). In addition, individual diverters on tributaries and smaller irrigation entities will become involved as this process evolves. More than 50 individuals and irrigation entities have already stepped forward, indicating their desire to properly screen and provide for fish passage. (BOR) (YN) (WDFW) (Conservation Districts)
- Mitigate for the effects of barriers such as road culverts to both juvenile and adult anadromous and resident fishes. Existing culverts that block access to upstream rearing/spawning habitat need to be retrofitted to improve passage conditions (and those modifications should be evaluated in the field). (PNNL)
- Restore migratory access to the historic range of anadromous fishes through construction of fishways, screens, pumps and on-farm irrigation systems that will allow safe access to productive spawning and rearing habitats in key tributaries. (YN)

- Screen all water diversions and irrigation ditches which may create low water barriers and increase stranding of bull trout in the Yakima core area (e.g., Beck Diversion, John-Cox Ditch, Wapato Irrigation Project Diversion, Rattlesnake Creek, Teanaway River). (WDFW)
- Replace culverts that are passage impediments. Continue operation and maintenance of BOR owned and some BPA owned fish passage and protection facilities.
- Work with other entities to provide passage for anadromous fish in Yakima basin tributaries; identify fish barriers or unscreened diversions; and develop solutions that allow for fish passage. (BOR)
- Prevent fish mortalities, including of ESA-listed salmonids, caused by the Naches River Water Treatment Plant intake systems. (City of Yakima)
- Eliminate the disruption of fish habitat at the Fruitvale Irrigation Canal diversion site on the Naches River as currently occurs during annual in-river maintenance. (City of Yakima)
- More efficient conveyance and use of water withdrawn from the Naches River for the City of Yakima is needed. (City of Yakima)

Research, Monitoring and Evaluation

WDFW Vegetation Monitoring

Habitat evaluation procedures (HEP) will be conducted by WDFW wildlife area staff, Vegetation Management Team personnel, and volunteers every five years to monitor :general habitat trends. At least two baseline transects will be replicated in each cover type for each area evaluated. Areas will be selected on the basis of differences in cover type, management history, and current management/restoration protocols. Data on shrub and herbaceous cover (Daubenmire 1970), visual obstruction (Robel et al. 1970), and species composition will be systematically collected using standard techniques. HEP surveys will be conducted within the same general time frame and location as the original baseline transects to ensure similar plant phenology. All transects will be documented with standard photographs.

Substantial areas of noxious weeds will be mapped and monitored every two years. Standard and periodic photographs will be taken at each area monitored. Site specific enhancement/maintenance monitoring will be done with similar techniques, but with more flexibility in periodicity (every 1 to 5 years). All techniques will be designed to be rigorous under field conditions, to produce data that is statistically sound when analyzed, and to document results that are potentially useful with regard to future management opportunities

Monitoring, such as the vegetation monitoring program described above, is an important component of adaptive management. Adaptive management consists of 4 basic steps: 1) resource objectives are developed to describe the desired condition; 2) management is designed to meet the objectives; 3) the response of the resource is monitored to determine if the management objective has been met; and 4) management is adapted (changed) if objectives are not reached. Monitoring provides the link between objectives and adaptive management.

Monitoring within Wenas Wildlife Area (WWA)

Monitoring includes both vegetation and wildlife. In addition, WDFW personnel and/or volunteers conduce neo-tropical bird surveys, sage grouse survey, mule deer/elk production counts, and hunter harvest surveys.

WWA, a BPA-funded mitigation project, provides habitat for both T&E species and Priority Habitat Species (PHS) and is an important link in WDFW's ongoing efforts to reverse downward population trends in shrub-steppe obligate wildlife species, such as sage grouse, and to improve water quality for both anadromous and resident fish alike.

- Resolve uncertainties about the role conditions in the lower Yakima River play in the natural production of the basin's fall chinook salmon; that is, address subyearling fall chinook survival; assess the quantity and quality of fall spawning and rearing habitat below Prosser and elsewhere; estimate channel fish predation more precisely; understand life histories of channel catfish and other non-native predators; and evaluate costs and benefits of increasing connectivity of lower Yakima River to the mainstem Columbia River, which would increase potential fall chinook habitat. (PNNL)
- The impact of uncontrolled urban runoff to anadromous fish-bearing streams needs to be determined. (YN)
- Identify and assess site-specific threats that are likely having a negative effect on the suitability of bull trout habitats used for spawning, rearing (adult and juvenile), migrating, and over-wintering. (WDFW)
- Investigate alternative means to reduce or eliminate the possibility of entrainment losses in the outlet works of all the storage dams. (WDFW)
- Investigate feasibility of providing fish passage at Keechelus, Kachess, Cle Elum, Bumping, and Rimrock Reservoirs, Clear Lake and Big Creek diversion dam. (WDFW)
- Evaluate reservoir operations as they relate to water level manipulations and provide recommendations to insure successful passage to and from natal streams for adfluvial bull trout populations. (WDFW)
- Assess the usefulness, cost, and feasibility of modifying the outlet works of all of the storage dams to provide enhanced water temperature control.
- Assess effects of residential and shoreline/floodplain development in known bull trout habitat (e.g., Lower Little Creek and Naches River). (WDFW)
- Inventory the distribution and status of westslope cutthroat, resident rainbow trout and other resident native fish species and to develop status reports similar to those developed for salmon, steelhead and bull trout in both streams and lakes, particularly alpine lakes.
- Determine the phenotypic and genotypic characteristics of progeny resulting from interbreeding between anadromous and resident forms of *O. mykiss* in the Yakima River basin. Additional genetic profiling of westslope cutthroat is needed (Trotter et al. 1999).
- Evaluate the impact of resident trout fisheries on anadromous fish, particularly ESA listed species such as steelhead and bull trout. Biologists need to evaluate the response of resident trout and anadromous fish populations to sport fishing regulations implemented since the late 1980's (WDFW 1984; Wright 1992). The impact of fish stocking practices, particularly downstream movement of fish from lakes and reservoirs is not known.
- Information regarding the lacustrine life-stage of bull trout is needed for all five basin reservoirs —Keechelus, Kachess, Cle Elum, Rimrock, and Bumping. (As discussed in

Limiting Factors, fragmentation and isolation of bull trout populations or subpopulations occurred as a result of the construction of water storage dams in the Yakima subbasin.)

- Determine the status of kokanee (*Oncorhynchus nerka*) in the Keechelus, Kachess, Cle Elum, Rimrock, and Bumping lakes. As an important prey source for bull trout in other systems, kokanee abundance is correlated with bull trout recruitment (Beauchamp and VanTassell, in press).
- All trophic levels in Keechelus, Kachess, Cle Elum, Rimrock, and Bumping lakes need to be studied in order to evaluate any bottom-up or top-down effects in the aquatic community.
- Assess the relative abundance, distribution and trophic interactions of the diverse fish assemblages in Keechelus, Kachess, Cle Elum, Rimrock and Bumping reservoirs.
- Supplement the Bureau of Reclamation’s limnological surveys (water quality, primary production and zooplankton dynamics): survey the fish community and conduct diet analyses. Bioenergetic analysis may also be needed to estimate bull trout consumption demands on kokanee and kokanee consumption demands on the standing crop of zooplankton, thereby quantifying the important trophic linkages affecting this sensitive species.
- Little information exists on the limnology and fish populations of the Yakima River Basin reservoirs. Mongillo and Faulconer conducted a limnological and fish survey in 1980-81 for WDFW and Heibert a lower trophic and water quality survey in 1998-99 for BOR. Mongillo and Faulconer’s study found all 5 reservoirs to be meso-oligotrophic to oligotrophic; however, the recent surveys by Heibert found the reservoirs to be ultra-oligotrophic. This difference could be due to the use of different lake classification indexes; however, if oligotrophication is occurring, then actions may be necessary to boost production back to a level which would maximize the spawning potential of the tributaries in each system.
- Monitor kokanee, burbot and lake trout fisheries to obtain harvest or catch rate data. All of these sport fish populations are self-sustaining, but recruitment, age structure and impacts of planktivory and piscivory have not yet been studied and need to be studied. (WDFW)
- Evaluate bull trout hybridization with brook trout and presence and effects of viable hybrids.
- Conduct intensive bull trout distribution and spawning surveys in the North and Middle Fork Teanaway, Cle Elum River, American River, Yakima River between Easton and Keechelus Lake, Cowichee Creek and other areas. Continue to conduct bull trout spawning surveys.
- Collect and analyze physical, chemical, and biological information on reservoirs in the Yakima Subbasin. (See additional needs above under Resident Fish).
- Determine movement and seasonality of use of different habitat types of adult and sub-adult migratory bull trout with specific emphasis on the mainstem Yakima River.
- Evaluate culvert modifications to determine if passage conditions have improved (PNNL)
- Evaluate management options for municipal aquifer and surface water withdrawals that would improve the timing of water extraction to minimize impacts on water supply.

Fish Physiology

- Continue monitoring the physiological development of Yakima hatchery spring chinook salmon to further evaluate and improve the ability of supplementation hatcheries to produce high quality smolts with morphological, physiological, behavioral, and life-history attributes similar to wild fish.
- Future studies should be conducted to more accurately determine the incidence of precocious male maturation in both wild and hatchery populations of Yakima spring chinook
- Future studies should be conducted at the Cle Elum Supplementation and Research facility to develop rearing strategies for controlling precocious male maturation in the hatchery population.
- At least three genetically distinct stocks of spring chinook salmon have been identified in the Yakima River. Increased levels of straying due to hatchery rearing or acclimation/release practices may have negative genetic and ecological impacts on existing wild populations. Future physiology studies of juvenile spring chinook should incorporate assessment of imprinting by juveniles released from different acclimation sites and ultimately compare these data with patterns of homing displayed by returning adults.

Other

- Obtain and utilize information from outside sources —with various state and federal agencies, other research programs, hatcheries, and university researchers—regarding environmental and harvest-related impacts on all anadromous salmonids occurring outside the Yakima basin. (YN)
- Creative cooperation among agencies and organizations is needed to be able to go beyond the minimum mandatory mitigation when opportunities arise to benefit fish and wildlife. (County of Yakima)

Wildlife

Wildlife Populations

For many species of a lack of information is the a significant limiting factor. For these species effective survey and monitoring techniques need to be developed and implemented, and/or a better understanding of ecology, demographics, and life histories needs to be gained. Recovery plans need to be written for native species that are in decline. Species in danger of becoming listed as threatened or endangered need to have their ranges expanded into currently unoccupied habitats and/or population densities increased within currently occupied areas. Increased public awareness of wildlife related issues throughout the subbasin is also needed.

Wildlife Habitats

For most wildlife species limited by habitat availability, key habitat areas need to be identified, protected, enhanced, restored and managed to provide ecological, cultural, and sociological benefits. Vegetation and hydrologic processes need to be restored where appropriate. Habitat connectivity needs to be improved to reduce the negative effects of habitat fragmentation. Habitat restoration techniques that are feasible over large landscapes need to be developed and monitored, and the information gained shared between agencies and private landowners.

Amphibians

Needs identified by McAllister et al (1999), McAllister (Pers. Comm., 2001), and Nordstrom and Milner (1997) for amphibians include:

- Protection of habitats
- Development of effective survey and monitoring techniques
- Baseline surveys and inventories
- Monitoring of populations
- Protection from introduced species, such as bullfrogs

Reptiles

Needs identified by Hays et al (1999), McAllister (Pers. Comm., 2001), Nordstrom and Reiner (1997), and Nordstrom and Whalen (1997) for reptiles include:

- Protection of habitats
- Baseline surveys and inventories
- Monitoring of populations
- Gain a better understanding of ecology and life histories

Waterfowl

Many plans have identified the needs of waterfowl in the Yakima Subbasin (Lloyd et. al 1993, Meuth 1989, Parker 1989, Bich et. al 1991, Ratti and Kadlec 1992, YN 1994, YN 2001).

These needs can be categorized as follows:

Breeding –

- Restore floodplain hydrology in riparian wetland areas to provide habitat
- Increase amount and quality of nesting cover
- Increase amount and quality of brood rearing habitat
- Management of waterfowl habitats to maintain quality
- Continue to monitor breeding activity (pair counts, nest surveys)
- Continue research pertaining to waterfowl use of irrigation projects

Migration and Wintering

- Restore floodplain hydrology in riparian wetland areas to provide habitat
- Increase the amount and availability of field grains in the Lower Subbasin
- Increase the amount of moist soil habitats in floodplain areas
- Restore agricultural habitats for nesting and brood rearing
- Increase quality of waterfowl reserve areas
- Continue summer banding efforts to monitor migration and survival

Bald Eagle (Haliaeetus leucocephalus)

Needs for bald eagles include (USFWS 1986):

- Management and protection of important eagle habitats (nesting, roosting, foraging), including primary and potential habitats
- Augmentation of populations
- Increased law enforcement and public awareness
- Continued research on eagle requirements to provide future management direction.

- Continued monitoring of eagle populations and productivity.

Peregrine falcon (Falco peregrinus)

Needs for peregrine falcons include (USFWS 1982, 1991):

- Habitat protection, especially nest sites, potential nest sites and areas of prey concentrations
- Breeding and wintering surveys
- Population surveys of occupancy and reproduction, and analyses of eggshell thickness and contamination
- Population enhancement, including egg manipulation, fostering, and hacking
- Research on population dynamics, movements and contamination
- Monitoring programs to ensure populations remain viable

Sandhill Crane (*Grus canadensis*)

Needs for sandhill cranes include:

- Monitor long-term population trends
- Identify historical nesting areas
- Restore nesting habitat
- Manage nesting habitat to ensure reproductive success of breeding population
- Identify key lands for conservation easements and/or acquisition
- Manage nesting habitat to ensure reproductive success of breeding population

Beaver (Castor canadensis)

Needs for beavers in the subbasin include:

- Development and initiation of standardized, objective population monitoring systems
- Restoration of wetlands and riparian habitats, especially in higher elevation areas of the subbasin

Forest Carnivores

Needs identified by US Fish and Wildlife Service (1993), Lewis (Pers. Comm., 2001) and WDFW (www.wa.gov/wdfw/wlm/diversty/soc/graywolf.htm) for forest carnivores include:

- Protection of habitats
- Conduct baseline surveys and inventories
- Monitor populations
- Protection from human-caused mortality
- Maintenance of adequate prey base
- Gain a better understanding of ecology and life histories
- Investigation of population dynamics
- Development of recovery plans

Forest Raptors

Needs for forest raptors include:

- Manage nesting habitat to ensure reproductive success of breeding populations
- Protect mature forest nesting habitats
- Provide habitats that include major components of large diameter trees
- Identify historic nesting areas
- Restore nesting habitat through appropriate forestry treatments (thinning, prescribed fire, etc)

- Monitor long-term population trends
- Continue research, including territory size and food habits.
- Identify key lands for conservation easements and/or acquisition

Migratory Songbirds

Needs for migratory songbirds include:

- Protect and manage nesting habitat to ensure reproductive success of breeding population
- Monitor long-term population trends
- Identify historical nesting areas
- Restore nesting habitat
- Identify key lands for conservation easements and/or acquisition

Cavity Excavators

Needs for cavity excavators include:

- Manage habitat to ensure reproductive success of breeding populations
- Provide habitats that include major components of large diameter trees
- Protect mature conifer forests, riparian habitats and oak woodlands
- Restore large diameter tree components through appropriate forestry treatments
- Control snag cutting for firewood
- Reduce road densities to reduce snag cutting
- Monitor long-term population trends
- Continue research into habitat needs and associations
- Educate forest users to the value of snags and wildlife tree habitats
- Identify key lands for conservation easements and/or acquisition

Big Game (Deer, elk)

Needs for big game species include:

- Protection of habitats, especially winter range and riparian habitats
- Better demographic and population monitoring
- Investigations of population dynamics
- Reduction of road densities

Shrub Steppe Associated

Ferruginous Hawk (Buteo regalis)

- Improved ferruginous hawk nest occupancy and success
- Assess possible affects of contaminants on survival and nest occupancy rates and relate these to hawk movements

Burrowing Owl (Speotyto cunicularia)

- Monitoring to detect changes in burrowing owl populations
- Inventories of occupied burrows in areas with high burrowing owl densities
- Identification of habitat needs

Golden Eagle (Aquila chrysaetos)

- Improve understanding of golden eagle baseline ecology in the Yakima Subbasin specifically food habits, and the relationship of shrubsteppe prey to nest occupancy and productivity

- Assess possible contaminant loads in golden eagles and determine year-round movements of locally breeding golden eagles from satellite telemetry.

Sage grouse (Centrocercus urophasianus)

- Reduction (through restoration) and prevention of further degradation and fragmentation of large contiguous blocks of shrubsteppe habitat.
- Expansion of sage grouse range into currently unoccupied areas.
- Evaluation of potential habitat that is currently unoccupied
- Restoration of the shrubsteppe herbaceous species (grasses and forbs) on a landscape scale
- Restoration of sagebrush in areas where the shrubsteppe herbaceous component already exists

Shrub Steppe Migratory Songbirds

Needs for sage thrasher, loggerhead shrike, sage sparrow, Brewer's sparrow and others in the subbasin include:

- Reduction (through restoration) and prevent further degradation and fragmentation of large contiguous blocks of shrubsteppe habitat
- Improved monitored to detect changes in their populations

Pygmy Rabbits (Brachylagus idahoensis)

- Surveys for possible pygmy rabbit presence in potential habitat
- Restoration of shrubsteppe habitat with deep soils

Black-tailed (*Lepus californicus*) and White-tailed (*Lepus townsendii*) Jackrabbits

- Develop monitoring to detect changes in jackrabbit populations
- Investigate apparent population decline and habitat relationships

Western Gray Squirrel (Sciurus griseus)

Needs identified for management and enhancement of western gray squirrels include:

1. Conduct study of impacts from timber harvest on western gray squirrel habitat use
2. Develop methodology to adequately monitor population trends
3. Conduct additional surveys on the Yakama Indian Reservation for western gray squirrel population distribution
4. Identify and acquire important lands to maintain or increase western gray squirrel population and improve travel corridors between key population centers
5. Evaluate threat from eastern gray squirrel range expansion in western gray squirrel habitat

Butterflies

Needs identified by Potter et al (1999) and Larsen et al (1995) include:

- Protection of habitats
- Inventory, surveys and monitoring of butterfly populations
- Maintenance and restoration of habitats
- Further investigation of the ecology and life history requisites of butterflies

Bats

Needs for bats include:

- Protect key roost and hibernacula habitats to ensure reproductive and overwintering success
- Perform baseline studies to determine species present and habitat associations
- Monitor long-term population trends

Bighorn Sheep (Ovis Canadensis)

Needs identified for bighorn sheep include:

- Protection of habitats
- Removal of domestic sheep from bighorn sheep range
- Monitoring of populations

Mountain Goats (Oreamnos americanus)

Needs identified for mountain goats include:

- Reduction of road densities in mountain goat habitats
- Monitoring of populations
- Investigation of population dynamics

Wildlife Habitat

Forested

Needs identified for forested habitats include:

- Protect remaining old forest stands, particularly ponderosa pine
- Re-introduce fire in maintenance of dry forests
- Protect healthy populations of Western white pine resistant to blister rust
- Maintain large tree components
- Decrease road densities
- Reduce fragmentation of forest habitats

Fringe/Transition

Winter Range

Needs identified for winter range habitats include:

- Protect from development, overgrazing and conversion to agriculture
- Appropriate fire management

Oregon White Oak *(Quercus garryana)*

Needs identified by Larsen and Morgan (1998) for white oak habitats include:

- Protection from development, overgrazing, conversion to agriculture
- Restoration of cyclic fire
- Protection from woodcutting

Riparian/Wetland

Needs identified for riparian habitats include:

- Reconnect normative hydrologic processes to floodplain habitats
- Reestablish cottonwood gallery forests
- Remove levees and dikes in priority areas
- Reconnect side-channel and wetland habitats
- Protect high quality habitats
- Restore areas that provide corridor connection

Wetlands

Needs identified for wetland habitats include:

- Reconnect normative hydrologic processes to floodplain habitats
- Reconnect side-channel and wetland habitats
- Protect high quality habitats
- Restore areas that provide corridor connection
- Manage wetland areas to maintain fish, wildlife and cultural benefits

Shrub Steppe

- Reduce (through restoration) and prevent further degradation and fragmentation of large contiguous blocks of shrubsteppe habitat
- Evaluate shrubsteppe restoration techniques and share information between agencies, tribes, private landowners and other groups involved in shrubsteppe restoration
- Develop and implement shrubsteppe restoration techniques that are economically feasible over large landscapes (e.g. establishing sagebrush by seed rather than by hand-planted rooted seedlings).
- Support education efforts on the value of shrub steppe habitats

Agricultural

- Habitat restoration on chronically idle or unfarmable lands
- Permanent vegetation restoration and management on canal and drain right-of-ways
- Development of wildlife habitat on edge, fence row and economically marginal lands
- Wetland restoration and management throughout the agricultural zone
- Utilization of tillage and harvest methods that allow waste grain to remain available to wildlife throughout the winter months

References

Abernethy, C.S., D.A. Neitzel, and E.W. Lusty. 1989. Velocity Measurements at Six Fish Screening Facilities in the Yakima River Basin. DOE/BP-01830-4, Prepared for the Bonneville Power Administration by Pacific Northwest Laboratory, Richland, Washington for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Abernethy, C.S., D.A. Neitzel, and E.W. Lusty. 1990. Velocity Measurements at Three Fish Screening Facilities in the Yakima River Basin. DOE/BP-01830-10, Prepared for the Bonneville Power Administration by Pacific Northwest Laboratory, Richland, Washington for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Abernethy, C.S., D.A. Neitzel, and W.V. Mavros. 1996. Movement and Injury Rates for Three Life Stages of Spring Chinook Salmon Oncorhynchus tshawytscha: A Comparison of Submerged Orifices and an Overflow Weir for Fish Bypass in a Modular Rotary Drum Fish Screen. Prepared by the Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Amaral, S. V., F. C. Winchell, and T. N. Pearsons. In press. Reaction of chinook salmon smolts and predators to behavioral guidance stimuli. Symposium on fish guidance technologies. American Fisheries Society Press.

Amaral, S. V., F. C. Winchell, and T. N. Pearsons. Submitted. Reaction of chinook salmon smolts to behavioral guidance stimuli. North American Journal of Fisheries Management.

Amoros, C., A. L. Roux, J. L. Reygrobellet, J. P. Bravard, and G. Pautou. 1987. A Method For Applied Studies of Fluvial Hydrosystems. Regulated Rivers, Vol. 1, 17-36.

Anderson, Lisa R. 1996. The unauthorized use of federally developed water: A product of the reclamation era. Masters Thesis, Central Washington University.

Anderson, R.J., and A.M. Bruce. 1980. A comparison of selected bald and golden eagle nests in western Washington. Pp. 117-120 in R.L. Knight, ed., Proceedings of the WA Bald Eagle Symp., Seattle, WA.

Balon, E.K. 1984. Life Histories of Arctic Charrs: An Epigenetic Explanation of Their Invading Ability and Evolution. Pages 109-141 *in* L. Johnson and B.L. Burns, Editors. Biology of the Arctic Charr, Proceedings of the International Symposium on Arctic Charr, Winnipeg, Manitoba, May 1981. Univ. of Manitoba Press, Winnipeg.

Banci, V. 1994. Wolverine. In: Ruggiero, L.F., K.B. Aubrey, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski. The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the western United States. USDA Forest Service. Gen. Tech. Rep. RM-254. 184 pp.

Bartholow, J.M. 1989. Stream temperature investigations: field and analytic methods. Instream Flow Information Paper No. 13. U.S. Fish and Wildlife Service Biological Report 89(17), Fort Collins, Colorado.

Bats Conservation International. 2000. Website data.

Baxter, J.S., and J.D. McPhail. 1996. Bull trout spawning and rearing habitat requirements: summary of the literature. Fisheries Technical Circular No. 98. B.C. Ministry of Environment, Lands and Parks, Vancouver.

Baxter, J.S., E.B. Taylor, R.H. Devlin, J. Hagen, and J.K. McPhail. 1977. Evidence for natural hybridization between Dolly Varden (Salvelinus malma) and bull trout (Salvelinus confluentus) in a north central British Columbia watershed. Canadian Journal of Fisheries and Aquatic Science. 54:421-429.

Beauchamp, D. A., and J. J. VanTassell In Press. Modeling seasonal trophic interactions of adfluvial bull trout in Lake Billy Chinook. Transactions of the American Fisheries Society.

Beckman, B.R. and Dickhoff, W.W. (1998b). Plasticity of smolting in spring chinook salmon: relation to growth and insulin-like growth factor-I. J. Fish Biology 53: 808-826.

Beckman, B.R., Dickhoff, W.W., Zaugg, W.S., Sharpe, C., Hirtzel, S., Schrock, R., Larsen, D.A., Ewing, R.D., Palmisano, A., Schreck, C.B., and Mahnken C.V.W. (1999). Growth, smoltification, and smolt-to-adult return of spring chinook salmon (*Oncorhynchus tshawytscha*) from hatcheries on the Deschutes River, Oregon. Trans. of the Am. Fish. Soc.128: 1125-1150.

Beckman, B.R., Dickhoff, W.W., Zaugg, W.S., Sharpe, C., Hirtzel, S., Schrock, R., Larsen, D.A., Ewing, R.D., Palmisano, A., Schreck, C.B., and Mahnken C.V.W. (1999). Growth, smoltification, and smolt-to-adult return of spring chinook salmon (*Oncorhynchus tshawytscha*) from hatcheries on the Deschutes River, Oregon. Trans. of the Am. Fish. Soc.128: 1125-1150.

Beckman, B.R., Larsen, D.A, Lee Pawlak, B., and Dickhoff, W.W. (1998a). The relationship of fish size and growth to migratory tendencies of spring chinook salmon (*Oncorhynchus tshawytscha)* smolts. N. Am. J. of Fish. Mgmt. 18: 537-546.

Beckman, B.R., Larsen, D.A, Lee Pawlak, B., and Dickhoff, W.W. (1998b). The relationship of fish size and growth to migratory tendencies of spring chinook salmon (*Oncorhynchus tshawytscha)* smolts. N. Am. J. of Fish. Mgmt. 18: 537-546.

Beckman, B.R., Larsen, D.A., Moriyama, S., Lee-Pawlak, B., and Dickhoff, W.W. (1998a). Insulin-like growth factor I and environmental modulation of growth during smoltification of spring chinook salmon (*Oncorhynchus tshawytscha*). Gen. Comp. Endocrinol. 109: 325-335.

Beckman, B.R., Larsen, D.A., Sharpe, C.S., Lee-Pawlak, B., Schreck, C.B., and Dickhoff, W.W. (2000). Physiological status of naturally reared juvenile spring chinook salmon in the Yakima River: Seasonal dynamics and changes associated with smolting. Trans. of the Am. Fish. Soc. 128: 1125-1150.

Beckman, B.R., Larsen, D.A., Sharpe, C.S., Lee-Pawlak, B., Schreck, C.B., and Dickhoff, W.W. (2000). Physiological status of naturally reared juvenile spring chinook salmon in the Yakima River: Seasonal dynamics and changes associated with smolting. Trans. of the Am. Fish. Soc. 128: 1125-1150.

Behnke, R.J. 1980. A Systematic Review of the Genus *Salvelinus*. Pages 441-481 *in* E.K. Balon, Editor. CHARRS - Salmonid Fishes of the Genus *Salvelinus*. W. Junk Publishers, The Hague, The Netherlands.

Benke, R. J. 1992. Native trout of western North America. Amer. Fish. Society Monograph 6, Bethesda, MD. 275 pp.

Benke, R. J. 1992. Native trout of western North America. Amer. Fish. Society Monograph 6, Bethesda, MD. 275 pp.

Bernatowicz, J. 2000. Personal Comm. Wildlife Biologist, WA Dept of Fish and Wildlife, Yakima, WA.

Bettinger, K. A. and R. Milner. 2000. Sandhill Crane (Grus canadensis). In E. M. Larsen and N. Nordstrom, editors. Management Recommendations for Washington's Priority Species, Volume IV: Birds [Online]. Available http://www.wa.gov/wdfw/hab/phs/vol4/sndhlcrn.htm

Bevis, K.R.; Richards, J.; King, G. M.; and Hanson, E.E.; Food Habits of the Northern Spotted Owl at Six Nest Sites in Washington’s East Cascades. In Duncan, J. R., Johnson, D. H., and Nicholls, T.H.; eds. 1997. Biology and conseration of owls of the Northern Hemisphere: 2d international symposium; Gen. Tech. Rep. NC-190. St. Paul Mn. USDA Forest Service, North Central Research Station. 635 pp.

Bich, J., T. Hames, S. McCorquodale, J. D. Reichel, and W. P. Bradley. 1991. The Yakima Indian Nation wildlife mitigation plan. *Prepared for:* Norwest Power Planning Council, Portland, Ore. 62pp.

Blanton, S.L., D.A. Neitzel, and C.S. Abernethy. 1998. Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 1997. Prepared by the Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Blanton, S.L., G.A. McMichael, and D.A. Neitzel. 1999. Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 1998. Prepared by the Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Blanton, S.L., G.A. McMichael, and D.A. Neitzel. 2000. Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 1999. Prepared by the Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Bonar, S.A., M. Divens, and B. Bolding. 1997. Methods for sampling the distribution and abundance of bull trout/Dolly Varden. Washington Department of Fish and Wildlife Research Report No. RAD97-05. Olympia, WA. 48 p.

Bonneville Power Administration. 1990. Preliminary design report for the Yakima/ Klickitat production project, March, 1990. Submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-00245

Bonneville Power Administration. 1990a. Preliminary design report for the Yakima/Klickitat production project, Appendix A. Submitted FY 1990 to Bonneville Power Administration, Portland, Oregon. DOE/BP-00245-2

Bonneville Power Administration. 1996. Yakima Fisheries Project. Final Environmental Impact Statement. Bonneville Power Administration. Washington Department of Fish and Wildlife and Yakama Indian Nation. DOE/EIS-0169. 204 pp plus Appendices.

BPA. 1986. Wildlife Protection, Mitigation and Enhancement Planning for Grand Coulee Dam, Final Report - 1986. U.S. Department of Energy, BPA Division of Fish and Wildlife, Portland, Oregon.

BPA. 1990. Wildlife Impact Assessment: Bonneville, McNary, The Dalles, and John Day Projects, October 1990. U.S. Department of Energy, BPA Division of Fish and Wildlife, Portland, Oregon. Johnson, D.H. and T. A. O'Neil 2001 (in press) Wildlife Habitat Relationships in Oregon and Washington. Oregon State University Press, Corvallis, Oregon. pp. 768

Braatne, Jeffrey H., Stewart B. Rood, and Paul E. Heilman. 1996. Life history, ecology, and conservation of riparian cottonwoods in North America. Chapter 3, in *Biology of Populus and its Implications for Management and Conservation*. Stettler, R. F., H.D. Jr. Bradshaw, editors. NRC Research Press.

Brown, L.G. 1992. On the Zoogeography and Life History of Washington's Native Char; Dolly Varden *Salvelinus malma* (Walbaum) and Bull Trout *Salvelinus confluentus* (Suckley). Report #94-04. Washington Department of Wildlife, Fisheries Management Division, Olympia, WA.

Buckley, Wallace. 1936. A Geography of the Yakima Region. Ph.D. dissertation, Ohio State University.

Bull, E. L. and R. G. Anderson. 1978. Notes on flammulated owls in northeastern Oregon. Murrelet 59(1): 26-28.

Buss, I. O. 1964. Wildlife Ecology. Washington State University. Pullman.

Campbell, Marius R. and others. 1916. *Guidebook of the Western United States, Part A. The Northern Pacific Route, with a side trip to Yellowstone.* Department of Interior, United States Geological Survey. Bulletin 611. Government Printing Offices.

Cavender, T.M. 1978. Taxonomy and Distribution of the Bull Trout, *Salvelinus confluentus* (Suckley), from the American Northwest. California Fish and Game, 3:139-174.

CH2M Hill, 1998. Roza-Sunnyside Board of Joint Control water conservation plan for the Yakima River Basin Water Enhancement Project. Prepared by CH2M Hill for RSBOJC, Sunnyside, WA.

City of Yakima, General Activities Affecting the Yakima Subbasin.

Close, D. A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of

Collins, B.D., 1997, Application of Geomorphology to Planning and Assessment of Riverine Gravel Removal in Washington. Seminar on Geology and Geomorphology of Stream Channels, University of Washington, Seattle, WA.

Cooperative Western Range Survey. 1938. An analysis of Range Problems in Kittitas County Washington and a Plan for their Solution. U.S. Government Printing Office.

Cotton, J.S. 1904. Forage Problems in Eastern and Central Washington. Masters Thesis. Washington State University. Pullman, WA.

Crane, P.A., L.W. Seeb, and J.E. Seeb. 1994. Genetic relationships among *Salvelinus* species inferred from allozyme data. Canadian Journal of Fisheries and Aquatic Science 51 (Supplement 1): 182-197.

Crawford, B. A., 1979. The origin and history of the brood stocks of the Washington Department of Game. Washington Department of Game, Olympia, Washington. 76 pp.

Cuffney, T.F., M.R. Meador, S.D. Porter, and M.E. Gurtz. 1997. Distribution of fish, benthic invertebrate, and algal communities in relation to physical and chemical conditions, Yakima River basin, 1990. U.S. Geological Survey, Water Investigations Report 96-4280, Raleigh, North Carolina.

Darda, D. 2000. Pers. comm. Biology Professor. Central WA Univ., Ellensburg, WA.

Dauble, D.D., R.P. Mueller, and G.A. Martinson. 1994. Evaluation of water qualityconditions near proposed fish production sites associated with the Yakima Fisheries Project. Prepared by the Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Daugherty, C. H. and A. L. Sheldon. 1982. Age-determination, growth, and life history of a Montana population of the tailed frog (ascaphus truei). Herpetologica 38 (4): 46l-468.

Dickhoff, W.W., Beckman, B.R., Larsen, D.A., Mahnken, C.V.W., Schreck, C.B., Sharpe, C, and Zaugg, W.S. (1995). Quality assessment of hatchery-reared spring chinook salmon smolts in the Columbia River Basin. 292-302. *In* H. L. Schramm and R. G. Piper ed. Uses and Effects of Cultured Fishes in Aquatic Ecosystems. Bethesda, Maryland, American Fisheries Society.

Dickhoff, W.W., Beckman, B.R., Larsen, D.A., Mahnken, C.V.W., Schreck, C.B., Sharpe, C, and Zaugg, W.S. (1995). Quality assessment of hatchery-reared spring chinook salmon smolts in the Columbia River Basin. 292-302. *In* H. L. Schramm and R. G. Piper ed. Uses and Effects of Cultured Fishes in Aquatic Ecosystems. Bethesda, Maryland, American Fisheries Society.

Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Phase One Completion Report. Washington Department of Fish and Wildlife. Olympia. 39p.

Eitemiller, D. .J., M. L. Uebelacker, D. A. Plume, E. P. Arango and K. L. Clark. 2000. Anthropogenic alteration to an alluvial flood plain within the Yakima Basin, Washington. Pp. 239-244. IN P. J. Wigington, Jr. and R. L. Beschta (eds.). *Proceedings of the AWRA* 2000 Summer International Specialty Conference on Riparian Ecology and Management in Multi-Land Use Watersheds.

Eitemiller, D. J., H. Fraser, A. Sullivan, and M. Uebelacker. 1995. Traditional Resource Patterns in the Upper Yakima River Basin. Atlas. Central Washington University Map Library.

Erhlich, P., Dobkin, D. S., and Wheye, D. 1988. <u>The Birder's Handbook</u>. 1988. 785 pp.

Fast, D., J. Hubble, M. Kohn, B. Watson. 1991. Yakima River Spring Chinook Enhancement Study. Final Report. Bonneville Power Administration, Portland, OR. DE-A179-83BP39461.

Fender, Dan and Peter Hahn. 1994. Angler fish database information system users guide, AFD version 2.5. Washington Department of Wildlife, Fisheries Management Program. Olympia, WA. 39 pages.

Fien, S. 1994. Goshawks in upper Yakima Basin. Report to WDFW.

Flagg, Thomas and Thomas E. Ruehle. 2000. Cle Elum Anadromous Salmon Restoration Feasibility Study: Summary Of Research. Bonneville Power Administration, Portland, OR.

Forsman, E.D.; Meslow, E.C.; Wight, H.M. 1984. Distribution and Biology of the Spotted Owl in Oregon. Wildlife Monographs. 87: 64 pp.

Fraser, Henry F. 1996. Ecosystem management in the Cle Elum River drainage as related to ownership, scale and resolution. Masters Thesis, Central Washington University.

Fuller, D. J. 1990. A food analysis of the rainbow trout, *Oncorhynchus mykis*s, through three seasons on the Yakima River in central Washington. Masters Thesis, Central Washington University, Ellensburg, Washington.

Gellenbeck, Kathryn. 1999. A spatial and temporal analysis of riparian vegetation along Satus Creek on the Yakama Indian Reservation. Masters Thesis, Central Washington University.

Glauert, Earl T. and Merle H. Kunz, Editors. 1972. *The Kittitas Indians*. Ellensburg Public Library. Ellensburg. WA.

Goggans, R. 1986. Habitat use by flammulated owls in northeastern Oregon. M.S. Thesis. Oregon State Univ., Corvallis.

Golder Associates, 2000. City of Yakima, Water and Irrigation Division, Master Irrigation Plan. January 13.

Golder Associates, 2000. Final Report, Supplemental Alternatives Analysis, City of Yakima, Water and Irrigation Division. September 20.

Ham, K. D., and T. N. Pearsons. 2000. Can reduced salmonid population abundance be detected in time to limit management impacts? Canadian Journal of Fisheries and Aquatic Sciences 57:17-24.

Ham, K. D., and T. N. Pearsons. In Press. A practical approach for containing ecological risks associated with fish stocking programs. Fisheries.

Ham, K. D., and T. N. Pearsons. Submitted. What level of ecological impact can be detected in salmonid populations? Canadian Journal of Fisheries and Aquatic Sciences.

Hames, T. R. 1999. Lower Yakima Basin enhancement and restoration project – final report. *Prepared for:* N. Am. Waterfowl Wetlands Office, U. S. Fish Wildl. Serv., Arlington, Va. Coop. Agr. No. 14-48-98210-97-J018 42pp.

Hawkins, C. P., L. J. Gottschalk and S. S. Brown. 1988. Densities and habitat of tailed frog tadpoles in small streams near Mt. St. Helens following the 1980 eruption. J. N. Am. Benthol. Soc. 7 (3): 246-252.

Haydon, Rich. 1997. The concept of naturalness in natural resource and ecosystem management. Masters Thesis, Central Washington University.

Hays, D. W., and S. Desimone. 1999. Northern Goshawk Management Plan (in prep.). Washington Dept. of Fish and Wildlife, Olympia, WA. 20 pp.

Hays, D. W., M. J. Tirhi, and D. W. Stinson. 1998. Washington State status report for the sage grouse. Washington Department of Fish and Wildlife. Olympia. 62p.

Hays, D.W., K.R. McAllister, S.A. Richardson, and D.W. Stinson. 1999. Washington state recovery plan for the western pond turtle. Wash. Dept. Fish and Wildl., Olympia. 66 pp.

Hiebert, S. 1998. Progress Report Draft: Limnological surveys of five reservoirs in the upper Yakima River Basin, Washington. U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado.

Hindman, J. N., G. A. McMichael, J. P. Olson, and S. A. Leider. 1991. Yakima River Species Interactions Studies. Annual Report FY 1990 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-01483-1. 75 pp.

Hockersmith, E., J. Vella, and L. Stuehrenberg 1995. Yakima River radio-telemetry study: rainbow trout. Annual report submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-00276-3.

Hockersmith, E., J. Vella, L. Stuehrenberg, R.N. Iwamoto, and G. Swan. 1995. Yakima River radio-telemetry study: steelhead, 1989-93, Bonneville Power Administration, Portland, Oregon.

Hunn, E. S. 1990. Nch i-Wana-The Big River-Mid-Columbia Indians and Their Land. University of Washington Press, Seattle and London.

Independent Scientific Group, 1996. Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem: Development of an Alternative Conceptual Foundation and Review and Synthesis of Science underlying the Columbia River Basin Fish and Wildlife Program of the Northwest Power Planning Council, 584 p.Lestelle, L.C., L.E. Mobrand, J.A. Lichatowich, and T.S. Vogel. 1996. Applied ecosystem analysis -- a primer. EDT: the ecosystem diagnosis and treatment method. Project number 9404600, Bonneville Power Administration, Portland, OR.

Independent Scientific Group. 1999. Return to the River: Scientific issues in the restoration of salmonid fishes in the Columbia River. *Fisheries Management* 24:10-19.

Independent Scientific Group. 2000. Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem. Northwest Power Planning Council. Portland, OR.

Johnson, A., D. Norton, and B. Yake. 1986. Occurrence and significance of DDT compounds and other contaminants in fish, water, and sediment from the Yakima River Basin. Washington Department of Ecology, Publication No. 86-5, Olympia.

Johnson, N. K. 1963. The Supposed migratory status of the flammulated owl. Wilson Bull. 75(2): 174-178.

Johnson, Willard. 1994. The Yakima River corridor: Habitat potential and land use. Masters Thesis, Central Washington University.

Johnston, T. and P. Mongillo. 1991. Unpublished char investigations data from files. Washington Department of Wildlife, Fisheries Management Division, Olympia, WA.

Joy, J., and B. Patterson. 1997. A suspended sediment and DDT total maximum daily load evaluation report for the Yakima River. Washington Department of Ecology, Publication No. 97-321, Olympia.

Kelsall, J.P. 1981. Status report on the wolverine, Gulo gulo, in Canada in 1981. Ottawa, On: Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 47 pp.

Kilsgaard, C. W. & C. W. Barrett. 2000. Washington Wildlife-Habitat types; Oregon Wildlife-Habitat types; Washington Historic Wildlife-Habitat types; and Oregon Historic Wildlife-Habitat types. Northwest Habitat Institute, Corvallis, Ore.

King, Ed. 1997. Wet meadows in the upper Naneum Creek Basin: A case study of multiple use resources and ecosystem management. Masters Thesis, Central Washington University.

King, Gina. Wildlife Biologist, Yakama Nation, pers. comm. 2000.

Knutson, K. L., and V. L. Naef. 1997. Management recommendations for Washington's priority habitats: riparian. Wash. Dept. Fish and Wildl., Olympia. 181pp.

Knutson, K.L. and V.L. Naef. 1997. Management recommendations for Washington's priority habitats: riparian. Wash. Dept. Fish and Wildl., Olympia. 118 pp.

Kraemer, C. 1991. Unpublished char investigations data from files. Washington Department of Wildlife, Fisheries Management Division, Mill Creek, WA.

Krause, T. 1991. The Yakima. Fly Fisherman 22:40-43,76-78.

Krippner, Steven. 1996. The Iron Horse State Park: Increasing management challenges on a Washington State owned corridor. Masters Thesis, Central Washington University.

Lampman, Ben Hur. 1946. The Coming of the Pond Fishes. Binfords & Mort. Portland, Oregon. 177 pages.

Larsen, D. T. 1999. Duck nesting, and brood habitat use and survival within the Wapato Irrigation Project. *Prepared for:* The Yakima River Basin Water Enhancement Plan. Wildl. Resour. Manage., Yakama Nation, Toppenish, Wash. 24pp.

Larsen, E. M., and J. T. Morgan. 1998. Management Recommendations for Washington's Priority Habitats, Oregon White Oak Woodlands. Wash. Dept. Fish and Wildl., Olympia. 37pp.

Larsen, E.M., E. Rodrick and R. Milner, tech. eds. 1995. Management recommendations for Washington's priority species, Volume I: Invertebrates. Wash. Dept. Fish and Wildl., Olympia.

LaTourrette, J. 1996. Draft Yakima River Basin Focus Area implementation plan. *Prepared for:* Intermountain West Joint Venture, Salt Lake City, Utah

Lauckhart, J. B. 1953. Washington Pacific Flyway report. No. 24. Wash. Dep. Wildl., Olympia, Wash.

Leary, R.F. and F.W. Allendorf. 1997. Genetic confirmation of sympatric bull trout and Dolly Varden in western Washington. Transactions of the American Fisheries Society 126:715-720.

Leary, R.F., F. W. Allendorf, and S. H. Forbes. 1991. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Wild Trout and Salmon Genetics Laboratory Report 91/2. Division of Biological Sciences, University of Montana. Missoula, Montana. 32p.

Leopold, A. S., Gutierrez, R. J., Bronson, M. T. 1981. North American Game Birds and Mammals. 198 pp. Washington Department of Fish and Wildlife. 1999. Game Status and Trend Report. Olympia, Wash. 195pp.

Lewis, J. C. 1980. Sandhill crane. *In* G. Sanderson, editor. Management of migratory shore and upland game birds in North America, pages 4-43. University of Nebraska Press, Lincoln, Nebraska.

Lewis, J.C. and D.W. Stinson. 1998. Washington State status report for the fisher. Wash. Dept. Fish and Wildl., Olympia, 64 pp.

Lichatowich, J., L.E. Mobrand, L. Lestelle, and T. Vogel. 1995. An approach to the diagnosis and treatment of depleted Pacific salmon populations in freshwater ecosystems. Fisheries 20(1): 10-18.

Lloyd, T. M., R. Denny, and G. Constantino. 1983. Wintering waterfowl redistribution plan for the Columbia Basin of Oregon and Washington. Coop. Rep. U. S. Fish Wildl. Serv., Wash. Dep. Wildl., Ore. Dep. Fish Wildl. 45pp.

Marshall, D. B. 1997. Status of the white-headed woodpecker in Oregon and Washington. Audubon Society of Portland, Oregon.

Martin, S. W., J. A. Long, and T. N. Pearsons. 1995. Comparison of survival, gonad development, and growth between rainbow trout with and without surgically implanted dummy radio transmitters. North American Journal of Fisheries Management 15:494-498.

McAllister, K., 2001. Personal Communication. Wildlife Biologist. Washington Dept. of Fish and Wildlife, Olympia, WA

McAllister, K.R., W.P. Leonard, D.W. Hays, and R.C. Friesz. 1999. Washington state status report for the northern leopard frog. Wash. Dept. Fish and Wildl., Olympia, 36 pp.

McCorquodale, S. 2001. Personal Communication. Wildlife Biologist. Yakama Nation – Wildlife Resource Management, Toppenish, WA.

McDonnel, Lawrence J. 1999. *From* Reclamation to Sustainability: Water, Agriculture, and the Environment in the American West. University Press of Colorado.

McGahan, J. 1967. Quantified estimates of predation by a golden eagle population. J. Wildlife Man. 31:496-501.

McIntosh, B. A., J. R. Sedell, J. E. Smith, R. C. Wissmar, S. E. Clarke, G. H. Reeves and L. A. Brown. 1994. Historical changes in fish habitat for select river basins of eastern Oregon and Washington. *Northwest Science* 68**:**36-53.

McIntosh, B. A., J., S. E. Clark, J. R. Sedell. 1995. Summary report for Bureau of Fisheries stream habitat surveys, Yakima River Basin 1934-1942. Bonneville Power Administration, Portland, OR. DOE/BP-02236-5.

McIntosh, B. A., J., S. E. Clark, J. R. Sedell. 1995. Summary report for Bureau of Fisheries stream habitat surveys, Yakima River Basin 1934-1942. Bonneville Power Administration, Portland, OR. DOE/BP-02236-5.

McMichael, G. A. 1993. Examination of electrofishing injury and short-term mortality in hatchery rainbow trout. North American Journal of Fisheries Management 13:229-233.

McMichael, G. A. and T. N. Pearsons. In Press. Upstream movement of residual hatchery steelhead trout into areas containing bull trout. North American Journal of Fisheries Management.

McMichael, G. A., A. L. Fritts, and T. N. Pearsons. 1998. Electrofishing injury to stream salmonids; injury assessment at the sample, reach, and stream scales. North American Journal of Fisheries Management 18:894-904.

McMichael, G. A., and T. N. Pearsons. 1998. Effects of wild juvenile spring chinook salmon on growth and abundance of wild rainbow trout. Transactions of the American Fisheries Society 127:261-274.

McMichael, G. A., C. S. Sharpe, and T. N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Transactions of the American Fisheries Society 126:230-239.

McMichael, G. A., J. P. Olson, E. L. Bartrand, M. Fischer, J. N. Hindman, and S. A. Leider. 1992. Yakima River Species Interactions Studies. Annual Report FY 1991 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-01483-2. 177 pp.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Behavioral interactions among hatchery-reared steelhead smolts and wild *Oncorhynchus mykiss* in natural streams. North American Journal of Fisheries Management 19:948-956.

McMichael, G. A., T. N. Pearsons, and S. A. Leider. 1999. Minimizing ecological impacts of hatchery-reared juvenile steelhead on wild salmonids in a Yakima basin tributary.

Pages 365-380 in Eric Knudson et al. editors. Sustainable fisheries management: Pacific salmon. CRC Press, Boca Raton, FL.

Meinig, Donald W. *The Great Columbia Plain: An Historical Geography, 1805-1910.* University of Washington Press. Seattle, Washington.

Meuth, J. L. 1989. Waterfowl management plan for the Yakima Indian Reservation. U. S. Fish Wildl. Serv. contract report to Wildl. Resour. Manage., Yakama Nation, Toppenish, Wash. 190pp.

Meyerhofer, J.A. 2000. Naches River Water Treatment Plan Raw Water Intake Project. Final Report. Carollo Engineers. Prepared for the City of Yakima, WA.

Millspaugh, J., and J. Skalski. 1999. Guidance on wildlife assessment techniques for the Yakama Nation mitigation program. *Prepared for:* Yakama Nation Wildlife Resource Management, Toppenish, Wash. 53pp.

Mobrand Biometrics. 1999. Phase 1 completion report: EDT analysis of the Yakima and Klickitat Rivers. Report prepared for the Yakama Indian Nation by Mobrand Biometrics, Inc., Vashon Island, WA. May, 1999

Mobrand, L., L. Lestelle, and G. Blair. 1998. Completion report for the habitat-coho production model project. Mobrand Biometrics, Inc., Vashon, WA.

Mobrand, L.E., J.A. Lichatowich, L.C. Lestelle, and T.S. Vogel. 1997. An approach to describing ecosystem performance through the eyes of a salmon. Canadian Journal of Fisheries and Aquatic Sciences 54: 2964-2973.

Mongillo, P and L. Faulconer. 1980. Yakima fisheries enhancement study final report. Washington Department of Game, Applied Wildlife Ecology. Water and Power Resources Service contract number: 7-07-S0038. 171 pp.

Mongillo, P.E. 1993. The Distribution and Status of Bull Trout/Dolly Varden in Washington State. Report #93-22. Washington Department of Wildlife, Fisheries Management Division, Olympia, WA.

Mongillo, P.E. and L. Faulconer. 1982. Final Report: Yakima fisheries enhancement study phase II. Washington Department of Game Report.

Montgomery, David. 2000. Coevolution of the Pacific salmon and Pacific Rim topography. *Geology* 28,12:1107-1110.

Morace, J.L., G.J. Fuhrer, J.F. Rinella, S.W. McKenzie, and others. 1999. Surface-water-quality assessment of the Yakima River Basin in Washington: Overview of major findings, 1987-91. USGS, Wat. Res. Inv. Report, 98-4113, Portland, Oregon.

Morton, W.M. 1970. On the Validity of All Subspecific Descriptions of North American *Salvelinus malma* (Walbaum). Copeia, 1970(3):581-587.

Murdoch, A. R. 1995. The effects of the spawning activities of bridgelip suckers *(Catostomus columbianu*s) on the reproductive success of rainbow trout *(Oncorhynchus mykis*s) in

Murdoch, A. R., P. W. James, and T. N. Pearsons. Submitted. Spawning interactions between rainbow trout and bridgelip suckers in a small Washington stream. Transactions of the American Fisheries Society.

Musser, J., and T. McCall. 2000. Pygmy rabbit management. Washington Department of Fish and Wildlife. Olympia. 12p.

National Marine Fisheries Service. 1995. Screen Criteria. Juvenile Fish. Developed by National Marine Fisheries Service Environmental & Technical Services Division. Portland, OR.

Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1986. A Fisheries Evaluation of the Richland and Toppenish/Satus Fish Screening Facilities, Spring 1986. Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1990a. A Fisheries Evaluation of the Toppenish Creek, Wapato, and Sunnyside Fish Screening Facilities, Spring 1988. Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and E.W. Lusty. 1990b. A Fisheries Evaluation of the Westside Ditch and Wapato Canal Fish Screening Facilities, Spring 1989. Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, and G.A. Martenson. 1990c. A fisheries evaluation of the Westside Ditch and Town Canal fish screening facilities spring 1990. Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, E.W. Lusty, and L.A. Prohammer. 1985. A Fisheries Evaluation of the Sunnyside Canal Fish Screening Facility, Spring 1985. Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., C.S. Abernethy, E.W. Lusty, and S.J. Wampler. 1988. A Fisheries Evaluation of the Richland and Wapato Canal Fish Screening Facilities, Spring 1987. Prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Neitzel, D.A., S.L. Blanton, C.S. Abernethy, and D.S. Daly. 1997. Movement of Fall Chinook Salmon Fry <u>*Oncorhynchus tshawytscha*</u>: A Comparison of Approach Angles for Fish Bypass in a Modular Rotary Drum Fish Screen. Prepared by the Pacific Northwest National Laboratory for the Environment, Fish and Wildlife Division, Bonneville Power Administration, Portland, Oregon.

Nordstrom, N. and K. Reiner. 1997. California Mountain Kingsnake. Pages 8-1 to 8-5 in E.M. Larsen, ed. Management recommendations for Washington’s Priority Species, Volume III: Amphibians and Reptiles. Wash. Dept. and Wildl., Olympia

Nordstrom, N. and M. Whalen. 1997. Striped Whipsnake. Pages 9-1 to 9-5 in E.M. Larsen, ed. Management recommendations for Washington's Priority Species, Volume III: Amphibians and Reptiles. Wash. Dept. and Wildl., Olympia

Nordstrom, N. and R. Milner. 1997. Columbia spotted frog. Pages 4-1 to 4-14 in E.M. Larsen, ed. Management recommendations for Washington's Priority Species, Volume III: Amphibians and Reptiles. Wash. Dept. and Wildl., Olympia

Nordstrom, N. and R. Milner. 1997. Larch Mountain salamander. Pages 3-1 to 3-8 in E.M. Larsen, ed. Management recommendations for Washington's Priority Species, Volume III: Amphibians and Reptiles. Wash. Dept. and Wildl., Olympia, WA.

Norman, David K. 1998. Reclamation of Flood-Plain Sand and Gravel Pits as Off-Channel Salmon Habitat. *Washington Geology* 26:20-28.

Norman, David K. C. J. Cederholm, and W. S. Lingley. 1998. Flood Plains, Salmon Habitat, and Sand and Gravel Mining. *Washington Geology* 26:3-20.

Noss, R.F., E. T. LaRoe III, and J. M. Scott. 1995. Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation. Biological Report 28. U.S. Department of the Interior, National Biological Service, Washington D.C. 58pp.

Oliver, W. H. 1983. Farm-wildlife history, relationships and problems on the Yakima Indian Reservation. Wildl. Resour. Manage., Yakama Nation, Toppenish, Wash. 193pp.

Olson, A. and W.A. Hubert. 1994. Beaver: water resources and riparian habitat manager. Univ. of Wyoming, Laramie, WY.

Pacific Northwest River Basins Commission, 1970. Columbia-North Pacific Region Comprehensive Framework Study of Water and Related Lands, Appendix V, Water Resources, Volume 1, 543 p.

Parker, G.L. and Storey, F.B., 1916. Water Powers of the Cascade Range, Part III. Yakima River Basin. U.S. Geological Survey Water-Supply Paper 369, 169 p., 20 plates.

Parker, R. C. 1989. South central waterfowl management plan. Wash. Dep. Wildl., Olympia, Wash. 124pp.

Pearsons, T. N., and A. L. Fritts. 1999. Maximum size of chinook salmon consumed by juvenile coho salmon. North American Journal of Fisheries Management 19:165-170.

Pearsons, T. N., and C. W. Hopley. 1999. A practical approach for assessing ecological risks associated with fish stocking programs. Fisheries 24(9):16-23.

Pearsons, T. N., G. A. McMichael, E. L. Bartrand, M. Fischer, J. T. Monahan, and S. A. Leider. 1993. Yakima Species Interactions Study. Annual Report FY 1992 submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-01483-3. 98 pp.

Pearsons, T. N., G. A. McMichael, S. W. Martin, E. L. Bartrand, J. A. Long, and S. A. Leider. 1996. Yakima River Species Interactions Studies. Annual Report FY 1994. Submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-99852-3. 150 pp.

Pearsons, T. N., G. A. McMichael, S. W. Martin, E. L. Bartrand, M. Fischer, and S. A. Leider. 1994. Yakima River Species Interactions Studies. Annual Report FY 1993.

Submitted to Bonneville Power Administration, Portland, Oregon. DOE/BP-99852-2. 247 pp.

Pearsons, T. N., S. R. Phelps, S. W. Martin, E. L. Bartrand, and G. A. McMichael. In press. Gene flow between resident rainbow trout and steelhead in the Yakima basin: ecological and genetic evidence. *In* P. Howell and D. Buchannan editors, proceedings of the inland rainbow trout workshop. Malheur Field Station, Oregon.

Pearsons, T.N., G.A. McMichael, S.W. Martin, E.L. Bartrand, M. Fischer, and S.A. Leider. 1994. Yakima River species interaction studies. Annual report for FY 1992. Bonneville Power Administration, Portland, Oregon.

Plum Creek Timber Co. 1996. Multi-Species Habitat Conservation Plan, Central Cascades Mountain Range. Plum Creek Timber Co., Seattle, WA. 277 pp.

Plummer, F.G. 1900. Mount Rainier Forest Reserve, Washington. Twenty-first Annual Report of the United States Geological Survey, Part V, Forest Reserves.

Pogson, T. H., and S. M. Lindstedt. 1991. Distribution and abundance of large sandhill cranes, Grus canadensis, wintering in California's Central Valley. Condor 93:266-278.

Potter, A., J. Fleckenstein, S. Richardson, and D. Hays. 1999. Washington state status report for the mardon skipper. Washington Department of Fish and Wildlife, Olympia. 39 pp.

Pratt, L.K. 1992. A review of bull trout life history. In: Howell, P.j. and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of AFS Corvallis OR. 67 pp.

Probasco, S. 1994. River Journal, Volume 2; Yakima River. Frank Amato Publications, Incorporated. Portland, Oregon.

Pyle, R.M. 1974. Watching Washington butterflies. Seattle Audubon Soc., Seattle

Pyle, R.M. 1990. Audubon Society field guide to North American butterflies. Alfred A. Knopf, Inc., New York.

Raedeke Associates, Inc. 2000. Habitat evaluations procedures, wildlife management areas, Yakama Nation, Washington. *Prepared for:* Yakama Nation Wildlife Resource Management. Toppenish, Wash. 42pp.

Ratti, J. T., and J. A. Kadlec. 1992. Concept plan for the preservation of wetland habitat of the Intermountain West. *Prepared for:* North Amer. Waterfowl Manage. Plan, U. S. Fish Wildl. Serv., Portland, Ore. 146pp.

Reference: For more information, see Washington State Status Report for the Mardon Skipper (Potter et al 1999).

Reynolds, R. T. and B. D. Linkhart. 1987. The nesting biology of flammulated owls in Colorado, pp. 239-248 *in* Nero, R. W. et al. ed. Biology and Conservation of Northern Forest Owls. Symp. NProc. USDA Forest Service Gen. Tech Rept. Rm-142. Ft. Collins, CO.

Rieman, B.E., D.C. Lee, and R.F. Thurow. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River Basins. North American Journal of Fisheries Management. 17:1111-1125.

Rinella, J.F., S. W. McKenzie, and G. J. Fuhrer. 1992. Surface-Water-Quality Assessment of the Yakima River Basin, Washington: Analysis of Available Water-Quality Data Through 1985 Water Year. US Geological Survey Open-File Report 91-453, Portland, OR.

Rinella, J.F., S.W. McKenzie, and G.J. Fuhrer. 1992. Surface-water -quality assessment of the Yakima River Basin, Washington: analysis of available water-quality data through 1985 water year. U.S. Geological Survey, Open-File Report 91-453, Portland, Oregon.

Ring, T.E., and Watson, B., 1999, Effects of Geologic and Hydrologic Factors and Watershed Change on Aquatic Habitat in the Yakima River Basin, Washington: *in* Rodney Sakrison and Peter Sturtevant (eds.), 1999.

Ross, Alexander. 1855. *Fur Hunters of the Far West*. Volumes I. Smith, Elder, and Company. London England.

Ruediger, B., J. Claar, S. Mighton, B. Naney, T. Rinaldi, F. Wahl, N. Warren, D. Wenger, A. Williamson, L. Lewis, B. Holt, G. Patton, J. Trick, A. Vandehey, and S. Gniadek. 1999. Canada Lynx Conservation Assessment and Strategy. USDI Bureau of Land Management, USDA Forest Service, USDI National Park Service, USDI Fish and Wildlife Service. 120 pp.

Rummel, Robert. 1951. Some Effects of Livestock Grazing on Ponderosa Pine forests and Range in Central Washington. *Ecology* , Vol. 32, No. 4.

Safina, C. 1993. Population trends, habitat utilization, and outlook for the future of the sandhill crane in North America: a review and synthesis. Bird Populations 1:1-27.

Savvaitova, K.A. 1980. Comments on the "Systematic Review of the Genus *Salvelinus*". Pages 480-481 *in* E.K. Balon, Editor. CHARRS - Salmonid Fishes of the Genus *Salvelinus*. W. Junk Publishers, The Hague, The Netherlands.

Schroeder, M. A., D. W. Hays, M. F. Livingston, L. E. Stream, J. E. Jacobson, and D. J. Pierce. 2000b. Changes in the distribution and abundance of sage grouse in Washington. Northwestern Naturalist 81:104-112.

Sheffield, S. *In press*. Current status, distribution, and conversion of the burrowing owl in Midwestern and western North America. Proc. Second Int. Symp. On the Biol. And Concerv. of Owls of the North. Hemishere.

Snow, C. 1973. Golden Eagle. Habitat Management Series for unique or endangered species. Rpt. #7. USDI Bureau of Land Mgmt. Denver, CO.

Snyder, Eric and Jack Stanford. 2000. Review and Synthesis of River Ecological Studies in the Yakima River, Washington, With Emphasis on Flow and Salmon Habitat Interactions. Final Report. U.S. Bureau of Reclamation, Yakima, Washington.

Spruell, P. and F.W. Allendorf. 1997. Nuclear DNA analysis of Oregon bull trout Final Report to the Oregon Department of Fish and Wildlife Wild Trout and Salmon Genetics Laboratory Report 97/5. Division of Biological Sciences, University of Montana. Missoula Montana. 28 p.

Stanford, J. A. 1998. Rivers in the landscape: introduction to the special issue on riparian and groundwater ecology. *Freshwater Biology* 40(3):402-406.

Stanford, J. A. and J. V. Ward. 1993. An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. *J. N. Am. Benthol. Soc.* 12(1):48-60.

Stanford, J. A., J. V. Ward, W. J. Liss, C. A. Frissell, R. N. Williams, J. A. Lichatowich and C. C. Coutant. 1996. A general protocol for restoration of regulated rivers. *Regulated Rivers* 12:391-413.

Stanford, J.A. and Ward, J.V., 1988. The hyporheic habitat of river ecosystems. Nature, v. 335, No. 6185, pp. 64-66.

State of Washington. 1999. Statewide Strategy to Recover Salmon - Extinction Is Not An Option. State of Washington, Governor's Salmon Recovery Office. November, 1999. 325 pp plus Appendices.

State of Washington. 1999. Statewide Strategy to Recover Salmon - Extinction Is Not An Option. State of Washington, Governor's Salmon Recovery Office. November, 1999. 325 pp plus Appendices.

Stepniewski, A. 1999. The Birds of Yakima County, Washington. 278 pp.

Stinson, D. W. 2000. Draft Washington state recovery plan for the lynx. Washington Department of Fish and Wildlife, Olympia, Washington. 86 pp.

Storm, R.M and W.P. Leonard (eds). 1995. Reptiles of Washington and Oregon. Seattle Audubon Soc., Seattle, WA 176 pp.

Sullivan, Allan, E. 2000. The Expected Potential native Vegetation of the Kittitas Valley, Central Washington: A soils Based Approach to the Reconstruction of Vegetation Landscapes. Ph.D. Dissertation, Oregon State University. Corvallis, Oregon.

Sullivan, Allen. 1994. Selected small and ephemeral streams in arid central Washington state: A historical perspective with recommendations for salmon habitat enhancement. Masters Thesis, Central Washington University.

the pacific lamprey *(Lampetra tridentata*) in the Columbia River Basin. Bonneville Power Administration, Portland, Oregon. DOE/BP-39067-1.

Thompson, B. C., J. E. Tabor, and C. L. Turner. 1988. Diurnal behavior patterns of waterfowl wintering on the Columbia River, Oregon and Washington. Pages 153-167 *in* M. W. Weller, ed. Waterfowl in winter. Univ. Minn. Press, Minneapolis, Minn.

Trotter, Patrick C., B. McMillan, N. Gayeski, P. Spruell, R. Berkley – Washington Trout, 1999, Genetic and phenotypic Catalog of Native Resident Trout of the Interior Columbia River Basin Fiscal Year 1998 Report: Populations of the Upper Yakima Basin, 1999 Annual Report to Bonneville Power Administration, Portland, OR, Contract No. 98AP07901, Project NO. 9802600, 40 electronic pages (BPA Report DOE/BP-07901-1).

Tuck, Robert L. 1995. The impacts of irrigation development on anadromous fish in the Yakima Basin, Washington. Masters Thesis, Central Washington University.

U.S. Fish and Wildlife Service, 1986. Recovery Plan for the Pacific Bald Eagle. U.S. Fish and Wildlife Service, Portland, OR. 160 pp.

U.S. Fish and Wildlife Service,and Pacific Coast American Peregrine Falcon Recovery Team. 1982. Recovery Plan for the Peregrine Falcon. U.S. Fish and Wildlife Service, Denver, CO. 86 pp., Addendum. 1991.

Uebelacker, Morris L. 1980. Land and Life in the Naches River Basin. Naches and Tieton Ranger Districts. Wenatchee National Forest, Region 6, USFS.

Uebelacker, Morris L. 1984. *Time Ball: The Story of Yakima Indians and Their Land*. Yakama Nation. Toppenish, WA.

Uebelacker, Morris. L. 1986. Geographic exploration in the Southern Cascades of Eastern Washington: Changing land, people and resources. Ph.D. Dissertation, University of Oregon. Eugene, Oregon.

Umtanum Creek, Washington. Masters Thesis, Central Washington University, Ellensburg, Washington.

United States Department of the Interior. U. S. Fish and Wildlife Service. 1999. Status review of westslope cutthroat trout in the United States. Portland, OR and Denver, CO.

United States Dept of Agriculture: Interior Columbia Basin Ecosystem Management Project: Environmental Impact Statement. 1997.

United States Dept of Agriculture: National Agricultural Statistical Service: Census of Agriculture, information obtained from web site at http://www.nass.usda.gov/census/census97/highlights (accessed February 2000).

USDA and USDI. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Standards and guidelines for management of late successional and old growth forest related species within the range of the northern spotted owl.

USDA Forest Service – Wenatchee National Forest – Naches Ranger District. 1996. Naches Mainstem and Wenas watershed analysis. USDA – Forest Service, Naches, WA

Utter, F. M. 1994. Current understanding of genetic population structure of bull trout. Unpublished report for Don Chapman Consultants, Boise, ID.

Vaccaro, J.J. 1986. Simulation of streamflow temperatures in the Yakima River Basin, Washington, April-October, 1981. U.S. Geological Survey, Water Resources Investigations Report 85-4232.

Vander Haegen, W. M., F. C. Dobler, and D. John Pierce. 1999. Shrubsteppe bird response to habitat and landscape variables in eastern Washington. Conservation Biology 14:1145-1160.

Waldo, J.C. 2000. Yakima Basin Water Investment: An Action Agenda.

Walsh, D.F., J.G. Armstrong, T.R. Bartley, H.A. Salman, and P.A. Frank. 1977. Residues of emulsified xylene in aquatic weed control and their impact on rainbow trout. Report # REC-ERC-76-11. U.S. Bureau of Reclamation, Denver, CO.

Ward, J. V. and J. A. Stanford. 1995a. The serial discontinuity concept: extending the model to floodplain rivers. *Regulated Rivers* 10:159-168.

Ward, J. V. and J. A. Stanford. 1995b. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. *Regulated Rivers* 11(1):105-119.

Warren, Claude N. 1959. Wenas Creek, A Stratified Site on the Yakima River: Its Significance for Plateau Chronology and Cultural Relationships. Master Thesis. University of Washington.

Washington Department of Ecology. June, 2000. Tri-County Water Resource Agency and Yakima River Basin Watershed Planning Unit, Watershed Assessment: Yakiman River Basin, prepared by Economics and Engineering Services, Inc. Team, Grant # G9800288.

Washington Department of Fish and Wildlife. 1997. Sunnyside Wildlife Area, habitat evaluation procedures, survey workbook. Columbia River Wildlife Management Team.

Washington Department of Fish and Wildlife. 2001. Draft Yakima Elk Herd Management Plan. Wash. Dept. Fish and Wildl., Yakima, WA.

Washington Department of Fish and Wildlife. 1994. Draft Oak Creek Wildlife Area Management Plan. Olympia, Wash. 55pp.

Washington Department of Fish and Wildlife. 1994. Sunnyside Wildlife Area Management Plan. Olympia, Wash. 43pp.

Washington Department of Fish and Wildlife. 1995. Washington State recovery plan for the pygmy rabbit. Washington Department of Fish and Wildlife. Olympia. 73p.

Washington Department of Fish and Wildlife. 1996. Priority Habitats and Species List. 28 pp.

Washington Department of Fish and Wildlife. 1996. Priority Species and Habitats List. Olympia, WA. 28pp.

Washington Department of Fish and Wildlife. 1996. Washington state recovery plan for the ferruginous hawk. Olympia, Wash. 63pp.

Washington Department of Fish and Wildlife. 1997a. Washington State salmonid stock inventory: bull trout/Dolly Varden. Washington Department of Fish and Wildlife. 428 p.

Washington Department of Fish and Wildlife. 1997c. The watershed recovery inventory project report. Washington Department of Fish and Wildlife. Olympia, Washington. 10 p. + Appendices.

Washington Department of Fish and Wildlife. 1998. Sunnyside Wildlife Area Implementation Work Plan. Olympia, Wash. 84pp.

Washington Department of Fish and Wildlife. 1998. Washington Salmonid Stock Inventory: Appendix bull trout/Dolly Varden. (SaSI) Washington Department of Fish and Wildlife. 437 pp.

Washington Department of Fish and Wildlife. 1999. Draft Washington state recovery plan for the goshawk. Olympia, Wash. 20pp.

Washington Department of Fish and Wildlife. 1999. Game Status and Trend Report. Olympia, Wash. 195pp.

Washington Department of Fish and Wildlife. 2000. 2000 Game Status and Trend Report. Wildlife Program, Washington Department of Fish and Wildlife, Olympia, WA, USA.

Washington Department of Fish and Wildlife. 2000. Bull Trout and Dolly Varden Management Plan. Washington Department of Fish and Wildlife, Fish Management Program. Olympia, WA. 19 pp.
Washington Department of Fish and Wildlife. 2000. Bull Trout and Dolly Varden Management Plan. Washington Department of Fish and Wildlife, Fish Management Program. Olympia, WA. 19 pp.
Washington Department of Fish and Wildlife. 2000. Draft Yakima Elk Herd Plan. 25pp.

Washington Department of Fish and Wildlife. 2000. Fish Passage Technical Assistance. Screening Requirements for Water Diversions.

Washington Department of Fish and Wildlife. 2000. Wenas Wildlife Area Work Plan. 96pp.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993. 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). March. 1993, 212 pp.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993a. 1992 Washington State Salmon and Steelhead Stock Inventory: Appendix Three, Columbia River Stocks (SASSI). June, 1993, 580 pp.
Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993. 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). March. 1993, 212 pp.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993a. 1992 Washington State Salmon and Steelhead Stock Inventory: Appendix Three, Columbia River Stocks (SASSI). June, 1993, 580 pp.
Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes. 1993. 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). Mar. 1993. 212p.

Washington Department of Game. 1984. A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington. Washington Department of Game, Fisheries Management Division, Olympia, WA. 60 pp.
Washington Department of Game. 1984. A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington. Washington Department of Game, Fisheries Management Division, Olympia, WA. 60 pp.
Washington Department of Game. 1984. A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington. Washington Department of Game, Fisheries Management Division, Olympia, WA.

Washington Department of Natural Resources and Boise Cascade Corporation. 1996. Teanaway Watershed Analysis. Washington Dept. Natural Resources, Forest Practices Division, Olympia, WA

Washington Department of Natural Resources information Land Survey Unit, Wa. Dept of Natural Resources, Olympia, Wa. 2001.

Washington Department of Natural Resources. 1997. Final Habitat Conservation Plan. Olympia, 212 pp.

Washington Department of Resource Mapping Unit, Wa. Dept of Natural Resources, Olympia, Wa. 2000.

Washington Department of Wildlife. 1993. Status of the western gray squirrel (*Sciurus griseus*) in Washington. Unpub. Rep. Wash. Dept. Wildl., Olympia.

Washington Department of Wildlife. 1991. Management Recommendations for Washington's Priority Habitats and Species.

Washington Department of Wildlife. 1992. Draft Bull Trout/Dolly Varden Management and Recovery Plan. Washington Department of Wildlife, Fisheries Management Division, Olympia, WA. 125 p.

Washington Department of Wildlife. 1993. Status of the Larch Mountain salamander (*Plethodon larselli*) in Washington. Unpub. Rep. Wash. Dept. Wildl., Olympia.

Washington Department of Wildlife. 1994. Draft Steelhead Management Plan. Washington Department of Wildlife, Fish Management Program. April, 1994. 32 pp.

Washington Department of Wildlife. 1994. Draft Steelhead Management Plan. Washington Department of Wildlife, Fish Management Program. April, 1994. 32 pp.

Washington Fish and Wildlife Commission. 1995. Washington Department of Fish and Wildlife Goals, Policies, and Objectives by the Washington Fish and Wildlife Commission. Olympia, WA. 16 p.

Washington Fish and Wildlife Commission. 1997. Policy of Washington Department of Fish and Wildlife and Western Washington Treaty Tribes Concerning Wild Salmonids (WSP). Adopted by Washington Fish and Wildlife Commission December 5, 1997. Olympia, WA. 46 pp.

Washington Fish and Wildlife Commission. 1997. Washington Department of Fish and Wildlife Mission Statement. Adopted by Washington Fish and Wildlife Commission April 18-19, 1997. Olympia, WA. 1 p.

Washington Fish and Wildlife Commission. 1997a. Policy of Washington Department of Fish and Wildlife and Western Washington Treaty Tribes Concerning Wild Salmonids Adopted by Washington Fish and Wildlife Commission December 5, 1997. Olympia, WA. 46 p.

Washington Fish and Wildlife Commission. 1997b. Additional Policy Guidance on Deferred Issues Concerning Wild Salmonid Policy Adopted by Washington Fish and Wildlife Commission December 5, 1997. Olympia, WA. 21 p.

Watershed Management to Protect Declining Species. American Water Resources Association, Middleberg, Virginia, TPS-99-4, p. 191-194.

Watson, Rick and Jim Cummins. 2000. Upriver brights escapement sampling, 1999 annual report. Washington Department of Fish and Wildlife, Fish Management Program. August, 2000. Olympia, WA. 22 pages.

Watson, Rick and Paul LaRiviere. 1999. Pacific Salmon Commission, Letter of agreement upriver brights project, FY 1998 Second half progress report and FY 1998annual report. Washington Department of Fish and Wildlife, Fish Management Program. Yakima, WA. December 13, 1999. 18 pages.

WDF and WDW (Washington Department of Fisheries and Washington Department of Wildlife). 1993. 1992 Washington State salmon and steelhead stock inventory, Appendix three: Columbia River stocks. WDF and WDW, Olympia.

WDFW. 2001. Wenas wildlife area workplan 2001 (draft). Washington Department of Fish and Wildlife. Olympia, Washington. 128 pps.

Williams, Ken. 2000. Status review of *Oncorhynchus clarki lewisi* in Washington. Washington Department of Fish and Wildlife. Sport fish investigations in Washington State, October 1, 1998-June 30,1999 Progress report, Eastside volume. Federal Project No. F-115-R, pp.

Wright, S. 1992. Guidelines for selecting regulations to manage open-access fisheries for natural populations of anadromous and resident trout in stream habitats. North American Journal of Fisheries Management 12: 517-527

Yakama Nation. 2000. Draft Spotted Owl Management Plan. Yakama Nation – Wildlife Resource Management Program, Toppenish, WA

Yakima Indian Nation. 1990. Yakima River Subbasin Salmon and Steelhead Production Plan. Prepared by the Confederated Tribes of the Yakima Nation, Washington Department of Fisheries and Washington Department of Wildlife for the Northwest Power Planning Council and Indian Tribes of the Columbia Basin Fish and Wildlife Authority. 282pp.

Yerxa, Tracey. 1997. The changing value of water in the West: Yakima Water Basin Enhancement Project. Masters Thesis, Central Washington University.

Yerxa, Tracey. 2000. Fiscal year 1999 annual report. Yakama Nation Wetlands and Riparian Restoration Project. *Prepared for:* Bonneville Power Admin., Portland, Ore. Contract No. 96-BI-93554. 48pp.

YIN (Yakama Indian Nation), Washington Department of Fisheries and Washington Department of Wildlife. 1990. Yakima River sub-basin salmon and steelhead production plan. Columbia Basin Fish and Wildlife Authority, Portland, Oregon.